Improving the effectiveness of public health infographics through design principle application

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The candidate confirms that the work submitted is [his/her/their] own, except where work which has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

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Important note: This thesis was completed between October 2018 – April 2022 during the covid-19 pandemic. The pandemic coincided with the end of chapter 3 and impacted the rest of the work from this point. This is reflected in the remote methodologies employed in the later stages of the thesis.

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Abstract

Infographics have been recognised as an effective and accessible method of information communication, leading to their common use in the dissemination of public health information. However, current design outputs in this field are not frequently produced by information design specialists, resulting in variable design quality. This project looked to address this problem, by investigating the development process for a tool that would allow such users with limited design training to maximise the effectiveness of their infographic outputs. First, a literature review was conducted to define research-based design principles that were applicable to infographics. The value of these principles was then investigated, experimentally comparing user performance with 3 infographic design variations. These design variations applied the design principles to variable degrees; establishing that a high proportion of principles should be applied to maximise user performance. Next, the principles were reduced from 84 to 20, aiming to retain the most salient and maximising accessibility for the non-designer audience. These final principles were developed into motion graphic education resource, aiming to optimise adherence and teach this demographic to successfully apply the principles in their own design. The resource was later tested by conducting a generative design investigation that required 9 healthcare professionals to design a public health infographic, both before and after accessing the resource. Comparative experimental testing on these design outputs revealed that use of the motion graphics resulted in significantly more effective designs, measured by information location efficiency, memorability, and user opinion. This established a successful process for developing effective design education tools, and identified motion graphics as an efficient teaching technique. As well as establishing the needs of the healthcare professional target audience through an iterative user-centred design process. Finally, concluding that use of this resource can be used to maximise the effectiveness of public health infographics, providing potential advantages to the prevention of future disease and protection of the public health.

CONTENTS

1. Introduction

1.1 Background

The present world is often defined as 'the information age' where the internet has driven the ever-increasing consumption of digital data (Lankow et al., 2012). The vast amount of data presented to the modern individual has driven a need for the communication of complex information both quickly and more memorably (Otten et al., 2015). This can be achieved through the utilisation of the human visual system; visual information can be processed by the human brain at great speed (Smiciklas, 2012). Understanding of the power of visual communication has driven the field of data and information visualisation; and popularised visual information communication methods such as infographics. Infographics have been shown to reduce the cognitive load required to comprehend information, when compared to the same information in a written form (Martin et al., 2019).

An infographic, or information graphic, displays information efficiently through the combination of typography and accompanying graphic visualisation; aiming to make the information both clearer and more accessible (Lonsdale et al., 2019). Effectively designed infographics have the potential to more effectively communicate and simplify information, and enhance learning (e.g. Martix and Hodson, 2014; Shafipoor et al., 2016; Lonsdale et al., 2019). They can optimise a user's potential to both observe and comprehend complex information (Otten et al., 2015), proving useful across a variety of literacy levels, age and language abilities (Çifçi, 2016; Pisarenko and Bondarev, 2016; Baglama et al., 2017). Otten et al. (2015) recognise the effectiveness of using infographics to convey complex information, specifically in the communication of public health and science information. Infographics are said to be an important link between information producers and consumers. They state that effective infographics are designed through the utilisation of principles from fields such as psychology, graphic design and usability.

A report by Global Web Index investigated digital versus traditional media consumption. Their 2019 report found that the vast majority of world markets spent more time consuming digital information, in comparison to printed or more traditional forms of information communication (GlobalWebIndex, 2019). Such results are supported by

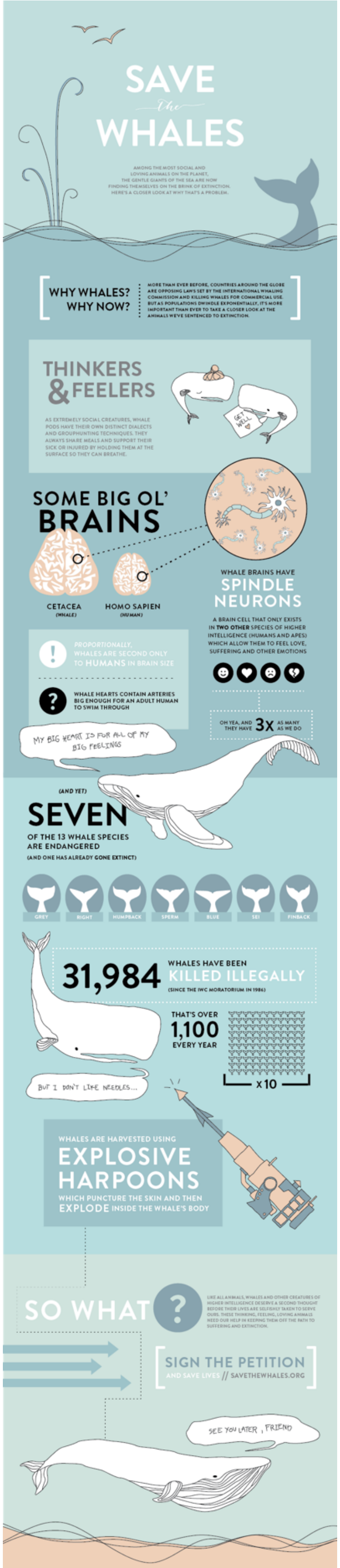
Ofcom (2019) in their most recent report detailing the increasing dependence on online mobile and screen devices for the consumption of media; driven, in part, by the rise in social media usage. Infographics have been used to display research abstracts summarised in a visually appealing format, resulting in an increase in publication engagement on social media. Both Huang et al. (2018a) and Thoma et al. (2018) found significantly greater abstract engagement in articles that were distributed on social media with an infographic that concisely displayed the results. The use of infographics in this context has also resulted in higher reader preference and lower cognitive load to review an abstract, offering an explanation for their increased engagement when compared to a written format (Martin et al., 2019). Hughes et al. (2021) found further support, identifying increased comprehension, preference, and recall of medical research in clinicians using infographics compared to written summaries; concluding that infographics are an effective method to disseminate key messages to researchers and patients worldwide. Given the recent expansion in information consumption, especially through social media, infographics present as seemingly appropriate medium for increasing engagement with information on these platforms.

The effectiveness of infographics also been recently recognised in health communication. Balkac and Ergun (2018) have acknowledged their use in patient education, describing them as an important tool in patient understanding of medical procedures, diseases, and topical healthcare issues. They state that health infographics can display complex health information in concise visual format that allows the information to be easily understood. When looking in context, the use of infographics has also been supported in communication between pharmaceutical companies and healthcare professionals (Patel et al., 2020), as well as patient education in concussion information (Provvidenza et al., 2019). They have also been suggested to motivate health promoting behaviour, and to support engagement and comprehension of patient health data (Arcia et al., 2016). The general consensus in healthcare infographic publications finds this visual communication method as a beneficial way to display this topic of information.

Infographics have also become a key method in public health communication. Public health is defined as “the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society” (Archeson, 1988; cited in WHO, 2022). Some of the worlds largest health organisations have taken note of the expansion of infographics and include infographics sections on their own websites, including: the World Health Organisation (WHO, 2021), Centre for Disease Control (CDC, 2022), and the UK Government website (GOV.UK, 2022). Prominent medical journals, such as the British Medical Journal (BMJ, 2022), also include infographic sections on their websites used to summarise published research findings.

An infographic appears to be a suitable way to promote important health messages to both prevent disease and prolong life, as has been exemplified in the COVID-19 pandemic. Many recent research publications have focused on the prominent use of infographics to disseminate important information related to the pandemic. Chan et al. (2020) found that a COVID-19 airway management infographic was widely distributed amongst healthcare professionals, concluding that it is an effective way to rapidly distribute important public health messages. Supporting research was published by Hamaguchi et al. (2020) in a similar study that found social media published infographics researched a wide public audience. They acknowledged the public enthusiasm for infographics and stated that they answered the need for the rapid dissemination of useful and accurate COVID-19 information. Infographics have also been shown to benefit COVID-19 behavioural safety changes. Lunn et al. (2021) found significantly better comprehension and recall of COVID-19 self-isolation information in participants using infographics compared to a written format. Similarly, both vaccine uptake (Crutcher and Seidler, 2021) and willingness to use face masks (Egan et al., 2021) was improved due to the distribution of infographics related to the topic.

The emerging field of infographics was relatively unexplored in primary research until recently. Though the effectiveness of infographics has been acknowledged in many different contexts, specifically in public health, the design of the infographics themselves are frequently not considered within the research publications. Kemp et al. (2021) acknowledges this in the context of COVID-19 information, citing their widespread use but lack of consideration of the effectiveness of the design. Given the efficiency of infographics in communicating information and the recent reliance by public health organisations on this method of information distribution, this project focuses on improving the effectiveness of public health infographics.



1.2. Definition of an 'infographic' and 'design principle'

In accordance to the Oxford English Dictionary, an infographic is defined as "a visual representation of information or data, e.g. as a chart or diagram" (Oxford English Dictionary, 2019). However, this definition is ambiguous and has the potential to include basic data visualisations that contain no supporting text information. Krum (2014) is more specific with their definition, stating an infographic is "a larger graphic design that combines data visualizations, illustrations, text, and images together into a format that tells a complete story". For the sake of this project, the second definition is a more accurate description of what an infographic represents.

Initial pre-study observation, using online search engines to explore the word 'infographic', revealed a list-based structure to be the most common type of infographic used to visualise complex information to the general public (e.g. public health, science information, business data, journalism articles). This is a top-to-bottom narrative structure where a subject is explained using a combination of image and accompanying text. An example of this list structure can be observed in Figure 1.1. Thus, for this project an infographic will be defined as a combination of images and graphs with accompanying text that displays information in an accessible narrative format.

Figure 1.1. Example of a list-based infographic that describes the topic of whale conservation.

The variation in the definition of an infographic causes difficulties in this field of research. Research publications sometimes define an infographic under another name, including 'information/data visualisation, 'data comic', 'graphics', and 'visual abstract' or they are included under broader term such as 'multimedia' or 'visualisation'. It is important to be aware of the various names given to an infographic when researching in this field. An example of the inconsistent definition causing confusion in this field is exemplified in a publication by Wang et al. (2019), who compared the effectiveness of different infographics. In their publication they compare the effectiveness and engagement of infographics, data comics and text displaying the same information. They recorded that data comics are rated higher in 3 of the 5 opinion measures (enjoyment, focus, overall engagement) and found the information to be better understood and remembered.

The definition of an infographic in relation to this project includes both the 'infographic' and 'data comic' compared by Wang et al. (2019). In fact, the clearer narrative format of the 'data comic' that was tested may fit the definition better than the 'infographic'. After viewing the examples of infographics and data comics used in the study (Figure 1.2), it can be argued that the 'data comic' could just be considered a better designed infographic using a more organised layout and additional structural elements, with a clearer linear format. It is clear that subjective differences in the definition of an infographic may affect the conclusions of research in the field of information design. In this project, an infographic is clearly defined and adhered to, also taking care to consider research that may use alternative definitions of an 'infographic'.

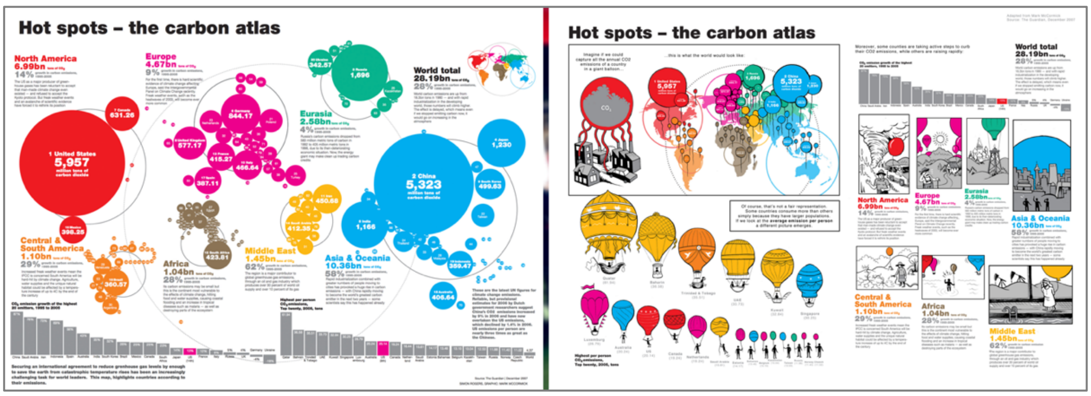


Figure 1.2. The infographic (left) and data comic (right) used in the research by Wang et al. (2019).

The term ‘principle’ or ‘design principle’ is also frequently referenced throughout the thesis. Fu et al. (2016) conducted a review into the use of the term ‘principle’, analysis of the various the definitions led them to define a principle as - “A fundamental rule or law, derived inductively from extensive experience and/or empirical evidence, which provides design process guidance to increase the chance of reaching a successful solution” (Fu et al., 2016). This thesis follows this definition, adapting it slightly to fit the content of the research. Here, a ‘design principle’ is defined as – A design rule derived from empirical evidence, which provides design process guidance to increase the chance of reaching an effective design solution. The term ‘design principle’ has been used previously in parallel contexts in publications in the field of communication design (e.g. Marcus, 1995; Valenstein, 2008; Midway, 2020), as well as infographic design (e.g. Stones and Gent, 2015a; Lonsdale and Lonsdale, 2019; Lonsdale et al., 2019). The term ‘guideline’ is used interchangeably, or in a very similar settings and with comparable definitions throughout the literature, though is said that a ‘guideline’ tends to be more content dependant (Fu et al., 2016). Other similar terminologies that describe comparable concepts include ‘suggestions’, ‘recommendations’ (e.g. Dunlap and Lowenthal, 2016), ‘techniques’, and ‘tips’ (e.g. Hernandez-Sanchez et al., 2021) (Fu et al., 2016). Given the lack of content dependency of the principles described in the thesis, as well as the existing use of the term in the field of infographic design, the term ‘design principle’ was selected.

1.3. Problem identification

The effectiveness of infographics in the communication of public health information has been clearly recognised. However, the quality of infographics is variable and rarely considered. Smit et al. (2014a) recognised that in the field of journalism, infographic design is often limited by a lack of usability testing and design guidelines. Also describing that effective infographic generation requires multidisciplinary skills including design, writing, editing, research, and data analysis, and successful designs are often a result of collaborate efforts between disciplines (Smit et al., 2014b). Though, interdisciplinary communication is often difficult. Stones and Gent (2015b) further acknowledged that within public health organisations, there is rarely a specific role created to design infographics. Instead, infographics are frequently designed by an in-house volunteer using inadequate software such as Microsoft PowerPoint and Excel, consequently lacking the quality of media infographics created on specialised design software. Given a core purpose of public health organisations is to communicate key healthcare messages, it appears particularly detrimental that the design output which conveys this important message may be ineffectively designed. The interview data with 15 public health professionals concluded that the demand for infographics is apparent, but improved support is needed to enable effective design outputs (Stones and Gent, 2015b).

The demand for infographics was amplified during the COVID-19 pandemic; infographics have been heavily relied on to communicate important public health information, and as previously recognised, have been shown to positively impact public knowledge and behaviour (e.g. Crutcher and Seidler, 2021; Egan et al., 2021; Lunn et al., 2021). However, their design quality is rarely considered within publications exploring the use of COVID-19 infographics. Kemp et al. (2021) acknowledge that many studies compare an infographic with a control group (e.g., written information), offering little guidance on how the infographic designs can be optimised to maximise effectiveness. Their own study compares infographic variations in the context of risk awareness and considers colour theory research to communicate risk information. However, no other research on the various other elements of infographic design outside of risk behaviour appears to be addressed, which could provide further beneficial guidelines in the design of the infographics they tested. The frequent use of infographics in practical settings, and more recently in research contexts, with little consideration on the effectiveness of the design demonstrates the need for this research project.

An initial scouting investigation of public health infographics was also completed in an attempt to understand the design quality of existing NHS infographics. The term 'NHS infographic' was searched on Google and any infographic created by the NHS in the search result of the first 5 pages of Google were included. A total of 18 infographics were collected, typically published by local NHS trusts. The infographics can be viewed in Figure 1.3. Most of the infographics appear to be of low quality, though this has not been tested. Design problems such as excessive colour application, disorganised layouts, poor text colour legibility, crowded appearances, and dated illustration appear to be common themes. Though, infographics 16 and 17 appear to be of higher quality than the others, so there is some variation evident in the infographics published by the NHS. It is acknowledged that the quality of these infographics has not been experimentally investigated, so the effectiveness of the designs is unclear. However, many of the infographics appear to display features that could be improved.

Despite the suggestion that public health infographics are infrequently optimally designed, research into creating effective infographics is appropriate even without explicit proof of this. Public health infographics display important information to the general public (Hamaguchi et al., 2020). Usable and attractive design is more likely to be engaged with (Tractinsky et al., 2000; Phongsatha, 2008), and engagement with infographics can positively influence behaviour in response to important key health messages (e.g. Crutcher and Seidler, 2021; Egan et al., 2021; Lunn et al., 2021). It would suggest that effective infographics have the potential to optimise engagement and adherence to public health campaigns. The importance of using effective infographics in public health appears evident, however it appears they may be being designed by individuals with limited design experience. A solution for this could be the implementation of a specific infographic design role within a public health organisation, although, this may not always be possible nor frequently practiced. An alternative solution lies in a process that trains and facilitates individuals from a non-design background in generating more effective infographic designs.

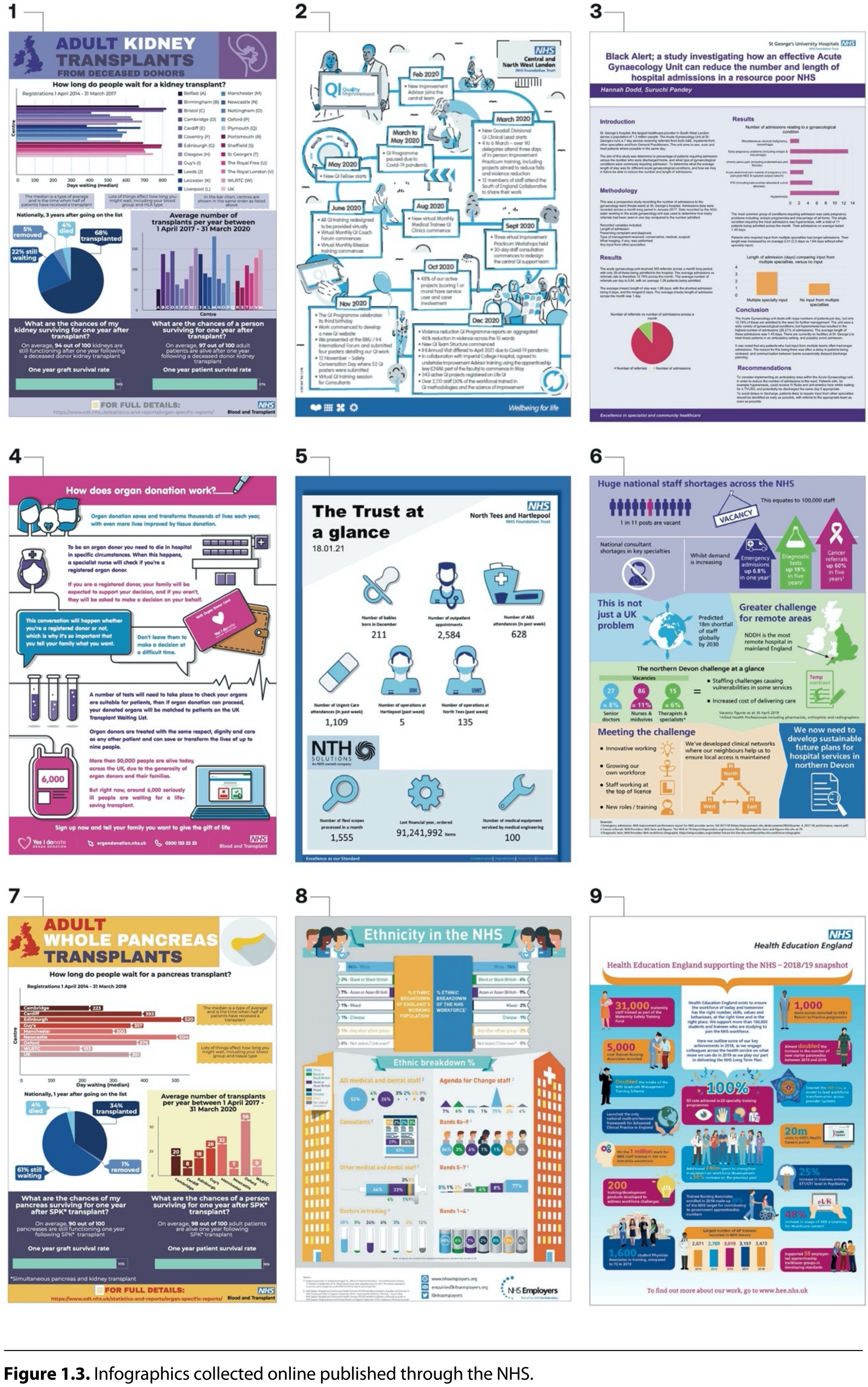


Figure 1.3. Infographics collected online published through the NHS.

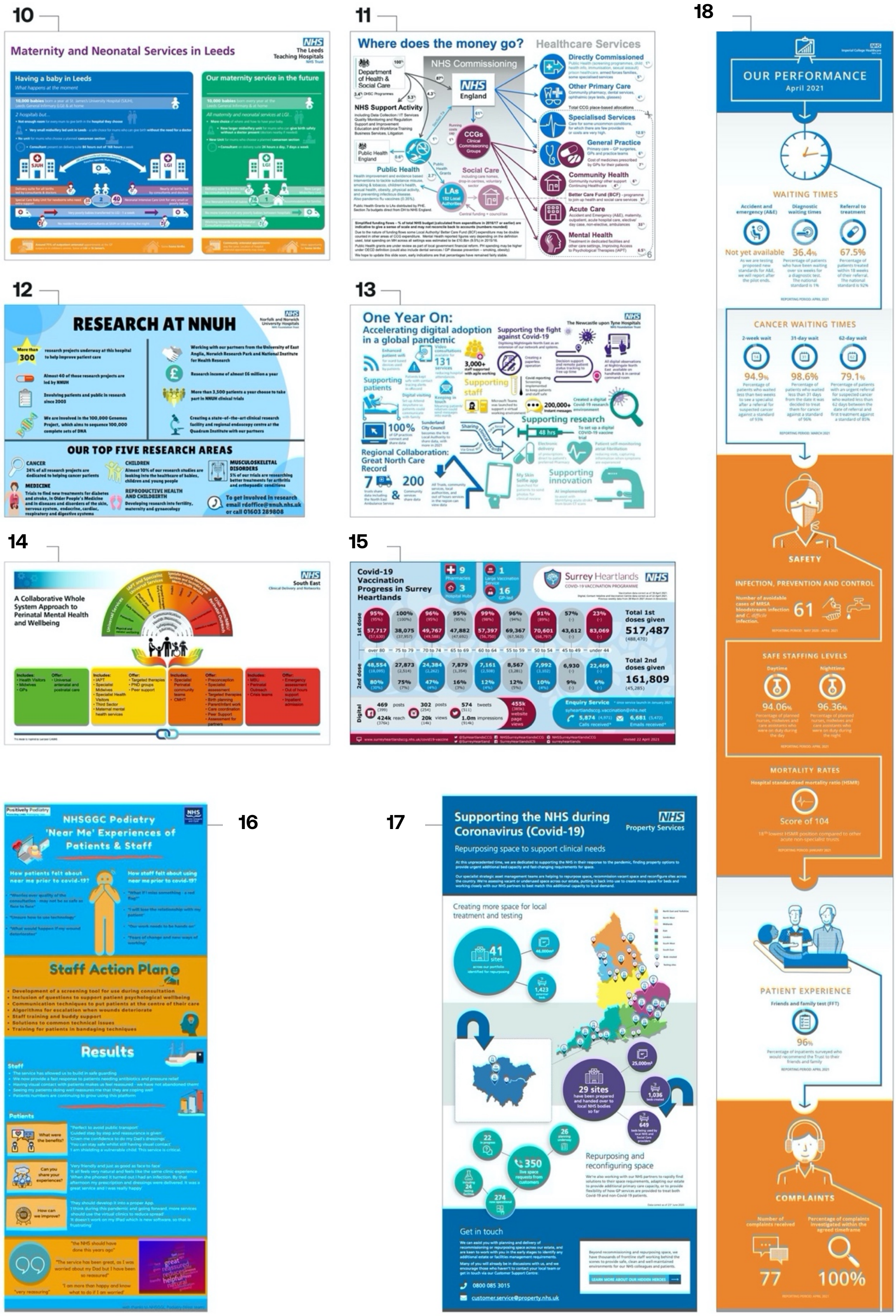


Figure 1.3 (cont.). Infographics collected online published through the NHS.

1.4. Thesis solution

A potential solution to the need for effective public health infographics is through the implementation of infographic design principles. A design principle is here defined as a fundamental guideline used to inform a design decision to create more effective design. The recent research into infographics has resulted in publications that have recognised the application of design principles as a method of creating effective design outputs. Otten et al. (2015) acknowledge the use of infographics to communicate public health information, and state that effective designs are those that utilise design principles. This project focused on design principles that have been established through the consolidation or completion of primary research. Many sources, such as websites and design textbooks, have defined design principles for infographics, yet many of these publications appear to be practice or opinion based. Though potentially beneficial, it cannot be assumed that opinion-based guidelines provide proven advantages to infographic design, and therefore only research driven publications are consulted.

One of the first publications to establish infographic design principles was generated by Stones and Gent (2015a). This directly addressed their previous work that described the results of interviews with 15 public health professionals, concluding that the demand for public health infographics was evident but more support was required to create effective design outputs (Stones and Gent, 2015b). This support was published in the form of a guide covering 7 core principles of public health infographic design (Stones and Gent, 2015a). The guide was targeted at anyone needing to design a public health infographic and used results from interviews, focus groups, and the review of academic literature in the definition of their principles. The principles were effectively described using corresponding examples and illustrations. Given the target audience of their guide, it was appropriate that the principles were condensed to only 7 simply described principles. Later, Dunlap and Lowenthal (2016) described design guidelines based on common features from popular infographics analysed using a novel application of the aesthetic learning experience framework (Parrish, 2009; Parrish et al., 2011). This alternative approach concluded with recommendations of structure, content, and visual design based on the highest scoring designs.

More detailed descriptions of infographic design principles have been published by Lonsdale and Lonsdale (2019). The GOV UK funded report considered both practice-based and research-based publications to define a large number of information visualisation principles, a larger category that included infographics. The report chapter specific to infographics described 117 design principles. In response to the recognised popularity and success of infographics in health, Hernandez-Sanchez et al. (2021) published 12 tips to produce successful medical infographics. Each principle was defined by referencing multiple research-based studies. However, the publication lacked any visual examples of how to use the principles that could have made the guidelines easier to use for the medical professional target audience. Though not specific to infographics, design principle definition has also been established in the field of multimedia learning. One of the leading researchers in the field, Professor Richard Mayer, has published design recommendation based on cognitive theory (e.g. Mayer and Moreno, 2003; Mayer, 2009).

The implementation of design principles has been shown to improve the effectiveness of visual information designs. Research by Professor Maria Lonsdale has recently investigated the effect of a combination of a user-centred iterative design process and design principle application in multiple design contexts. This design development method was found to significantly improve the recall accuracy and time efficiency of security webpage information, when comparing the original text-based design to a redesigned information visualisation strategy (Lonsdale et al., 2019). Further evidence can be observed in a later publication that used a similar method to improve the designs of patient information resources (Lonsdale et al., 2020b). Again, the surgery preparation information was found to show significantly improved performance measures in the leaflet redesigned to apply design principles, when compared to the original text heavy leaflet. Lonsdale et al. (2018) also compared 2 cyber security websites, one neglecting more website design principles than the other. Testing revealed that information was located significantly faster on the website that implemented more design principles; suggesting design principles create more effective designs in this context.

Additional support for the use of design principles has been observed in many other publications. Design principle application was again found to improve knowledge acquisition in patients using revised leaflets (McKenna and Scott, 2007). Short-term memorability of medical information was also improved in students after applying multimedia and design principles in lecture presentations (Issa et al., 2011). Additionally, design principle application was found to improve engagement in e-learning materials (Mulqueeny et al., 2015).

The use of design principles to improve visual design appears evident. Consequently, it presents as an appropriate method to maximise the design effectiveness of public health infographics. This project looked to first conduct an independent literature review to define any principles relevant to infographic design, focussing specifically on principles established through research-based publication. As later discussed in more detail, examples have been described that show principles may be difficult to follow for a non-designer. Subsequently addressed in chapters 4 and 5, the thesis also aimed to explore a practical method for design principle adherence by the target audience of non-designers. The aims and methodologies of this thesis are outlined below.

1.5. Thesis aims and methodologies

1.5.1. Thesis aims

The core aim of the thesis is to find an applicable method for the development of design education tools that can improve the effectiveness of public health infographics. The object was to define a practical technique that was suitable for both designers and those from a non-design background, although the target audience was healthcare professionals who typically have limited design experience. This was accomplished in 4 core stages that are covered in each chapter of this thesis:

1. Definition of infographics design principles.
2. Exploring the effectiveness of design application.
3. Design principle reduction and education resource development.
4. Testing the practical effectiveness of the education resource.

The research questions that are addressed through this project are as follows:

1. What design principles currently exist that are applicable to optimising communication via infographic design?
2. Does the application of design principles create a meaningful improvement in the effectiveness of public health infographics? And what level of principle application required to observe this potential improvement?
3. What methods can be developed that allows for the condensation and simplification of design principles?
4. Can the effectiveness of public health infographics be improved through the application of design principle by healthcare professionals?
5. Can a tool be developed that allow non-designers to easily understand and apply design principles to their own work? And how can this address the needs of the target audience (healthcare professionals)?
6. Are motion graphics an effective method of education to allow non-designers to understand and apply design principles?
7. Are some infographic design principles more impactful than others?

1.5.2. Target audience

The target audience of this research project is non-designers looking to maximise the learning potential of information they are communicating to the general public. This term “non-designer” is used frequently in the project. Here it is defined as an individual with limited design experience that has not undertaken a degree or is working in the field of graphic design (or related fields). This does not exclude a non-designer from creating a graphic design themselves. However, non-designers are less likely to create effective design outputs than an experienced graphic designer. Designers will be educated at university level within the field of graphic design (or related fields) and likely have an already established understanding of graphic principles, such as the Gestalt laws. So are typically able to create more effective infographic designs than those by non-designers. Non-designers, such as those working in fields like health, science communication, etc., could benefit from the understanding and application of infographic design principles.

Infographic design principles should be effectively and more easily utilised by someone who has been educated to understand them and how they should be applied, such as a designer. But for non-designers, a more bespoke approach to communicate these principles may be necessary to maximise adherence. There is a need for these principles to not only be established but also become accessible and easy to adhere to for a non-designer. This project also has the potential to be applicable to information designers looking to make more efficient infographics, who might only have tacit knowledge of specific principles. Designers may already be aware of some of the principles, but these come mostly from practice with very little research evidence to support them. The awareness and adherence to research-based principles has the potential to further maximise information comprehension from infographics.

For the purpose of this project, the emphasis is on non-designers looking to create effective public health infographics. This demographic appears to be more likely to create poor quality designs due to their inexperience and lack of understanding of basic rules of graphic design. If non-designers could be effectively educated in how to apply the most important infographic design principles this has potential for them to create significantly more effective infographic designs. The methodologies used to achieve this in this project are outlined below.

1.5.3. Methodology summary

The initial aim of the research was to establish effective research-based principles for the design of infographics; utilising existing research and exploring the application of these design principles to optimise infographic communication. Chapter 2 comprises an extensive literature review of the fields applicable to infographic design; including: cognition, Gestalt principles, colour, typography, hierarchy/structure and graphic design; with a view to establish the currently available research-based principles. Thus, resulting in the definition of 84 infographic design principles.

These principles, if applied effectively, have the potential to improve the effectiveness of a public health infographics. Chapter 3 looks to find clear evidence that the use of infographics principles results in a meaningful improvement in the effectiveness of public health infographics. To investigate the effectiveness of these principles, custom public health infographics of varying quality were designed. A 'good' infographic was created that applied 84/84 of the principle, an 'average' that applied 42/84, and a 'poor' design that applied 1/84 principles. A survey of existing infographics was also conducted to inform the principles applied to the 'average' design, looking to make it representative of current design standards. User performance with these 3 infographic designs was statistically compared, hypothesising that those participants using the 'good' design would perform best, and those using the 'poor' design the would perform the worst. Performance was measured by information location time, short and long-term information recall scores, and user opinion data. In addition, supplementary fixation and heat map data was collected using eye-tracking software during the study. Given the target audience of the project, later chapters focus on how to make infographic design principles accessible to an individual from a non-design background; aiming to allow for the generation of effective public health infographics by healthcare professionals.

The fourth chapter addresses two problems concerning the practicality of adhering to the infographic design principles defined in chapter 2. The aim of the chapter is to make the design principles as accessible and engaging as possible. First, it was acknowledged that it was unrealistic to ask non-designers to adhere to 84, often complex, design principles. So, this number had to be condensed. Second, these principles had to be displayed in a more engaging format than a written guideline. Consequently, chapter 4 utilises a 3-stage process to condense the number of principles. The final 20 principles were divided into 4 core categories, comprising 5 principles per category, covering: layout, colour, typography, and graphics. The titles and definition of the principles were also redefined to be as accessible as possible, simplifying any ambiguous design language. Given the aim of the chapter, next a design development stage is employed to maximise the accessibility of the 20 condensed principles. Motion graphic videos were chosen as an appropriate education method. A video for each core category was created, employing a user centred approach to utilise 2 stages of usability testing. These videos defined the principles, then used a step-by-step process to show how to apply each principle in the creation of an infographic. A supplementary pdf was also created to summarise the 20 principles. The potential effectiveness of the resource is explored in the final chapter.

The final chapter looks to explore whether the education resource could create a meaningful improvement in the effectiveness of infographic outputs created by healthcare professionals. First, a design generation stage was completed with 9 healthcare professionals using a heuristic generative design approach. Initially, they were required to create a heart attack infographic on Google Draw using the supplied written information and a choice of graphs. Next, they were asked to use the education resource by watching the 4 motion graphic videos and reading the summary pdf. Finally, they were asked to repeat the infographic design stage using the same information and process but attempting to apply the principles they had learned from the motion graphics. The 3 infographics that were most improved, in terms of principle application, were taken to a later stage of testing. A remote comparative study was then conducted with the general public using 60 participants, equally divided into two groups. The first group used the 3 infographics that had been designed with no input, the second group used those that had been designed after accessing the education resource. It was hypothesised that the second group would perform better due to the more effectively designed infographics. Similar performance measures were collected to those used in the research discussed in chapter 3; examining infographic location time, recall accuracy, recall time, as well as collecting user opinion data.

1.6. Summary and research significance

The research questions were addressed throughout the chapters of this project. This looked to address a problem that had been identified in response to the popularisation of infographics to communicate public health information. Infographics appear to be becoming ever prevalent and key in the dissemination of key public health messages. The project aimed to find a potential solution to the variable design quality and publication of infographics in this field by those with limited design experience. The development of a tool that can improve the design of public health infographics, as undertaken here, aims to establish practices resulting in meaningful benefits to future design. This can then be used to identify a successful process for developing effective design education tools. Given the public health information context of the thesis, this is explored with healthcare professionals, identifying their needs, and addressing them through an iterative design process. Given the reliance on infographics to distribute important public health messages, identifying tool that can be used to optimise the effectiveness of this visual communication method provides potential advantages to the prevention of future disease and protection of public health.

2. Chapter 2 - Establishing infographic design principles

2.1. Chapter 2 introduction

As discussed in the introduction, the application of design principles during the creation of infographics has the potential to improve infographic communication. The first stage of this process was to establish these infographic design principles, through the consultation of experimental research. Principles established in this field are often practice-based, as design is traditionally a practise-led field. However, it cannot always be assumed that practice-based guidance is valid; an absence of primary evidence results in a lack of confidence in the validity and reliability of such principles. Consequently, this literature review focuses instead on principles established through proven experimental research, with the objective to identify principles that will have a meaningful impact on the design features of an infographic.

For the purpose of this thesis, an infographic is defined as a graphic design that combines text, images, and data visualisations to simplify information and describe a subject in a narrative format (Krum, 2013). The literature review will focus on the design elements of an infographic as apposed to the information content. Although the overall focus of the project is on improving the communication of public-health related infographics, the review consulted research from fields outside of health infographic communication. A reason for this also being the minimal research currently available in health-related infographic design. This will allow the principles established here to be applicable to any infographic, no matter what the content of information.

2.1.1. Limitations of existing research

Some research has already taken place looking to establish infographic design principle guidelines. Dunlap and Lowenthal (2016) generated design guidelines based on common features from infographics deemed effective, collected from the 20 most liked infographics from a social media website. A novel analysis method to test an infographic's effectiveness was developed by the researchers using their own experience with the *aesthetic learning* experience framework (Parrish, 2009; Parrish et al., 2011).

However, both of the infographics scored highest in the analysis instrument contain text of low legibility due to the poor typographic design considerations. This may suggest that the aesthetic learning experience framework is useful in content consideration but could require further development to judge more specific design elements.

One example of research driven infographic guideline development was undertaken by Stones and Gent (2015a) who described a set of 7 basic principles for creating effective infographics to communicate healthcare information. This exists as one of the few examples defining infographic design principles. These guidelines are effectively researched and appropriately simplified as the target audience of the publication is healthcare professionals creating infographics. However, more detailed guidelines have the potential to further improve the design of infographics. One such resource was developed in a report by Lonsdale and Lonsdale (2019) that gathered research-based guidelines for information visualisation in greater detail. The publication contains an unparalleled assembly of research regarding information design principles, defining 486 principles from research and practice. Recently Hernandez-Sanchez et al. (2021) has considered the use of infographic design principles in the context of medical information. They defined 12 infographic design tips based on the consultation of appropriate research. The practical application of these infographic design guidelines have yet to be explored using experimental research. In comparison to the guidelines defined by Lonsdale and Lonsdale (2019), this literature review looks more specifically at infographics, rather than information visualisation as a whole, and focuses on research-based publications.

Evidence has been published in the field of multimedia learning supporting the use of cognitive principles in optimising the design of multimedia information (Mayer, 2010). Multimedia learning is described as learning with a combination of words and graphics (Mayer and Moreno, 2003); a larger category that includes infographics. The designs tested are often created without the application of information and typographic design principles, resulting in multimedia design that could be further improved. Examples of this can be observed in multiple multimedia information eye-tracking studies (e.g. Clinton et al., 2016; Jamet, 2014; Johnson and Mayer, 2012; Mason et al., 2013; Schmidt-Weigand et al., 2010), where cognitive principles are utilised but other design principles are ineffectively applied.

2.1.2. Literature review methodology

The following literature review focused on defining design principles applicable to infographics; only those principles that can be applied to this specific method of visual communication were consulted. The literature review was an extensive process attempting to consider the applicable research from multiple fields. It was completed between January 2019 and April 2019. Thus, any research publications that contradict or expand upon the literature covered in the review that were published after this date were not able to be consulted.

Experimental research exploring infographic principles is limited, so other appropriate fields were also consulted. The review started by consulting human cognitive processing models to understand why infographics make information comprehension and adherence more efficient. This led to establishing cognitive principles that can be utilised in infographic design, as well as Gestalt theories based on human visual perception patterns. Later, the review utilised Google Scholar and Web of Science to look at specific design elements that make an infographic. These databases were searched with the keywords “infographic”, “multimedia”, “information”, “information visualisation”, “colour”, “graphic(s)”, “layout”, “typography”, “text”, “gestalt”, “cognition” and “instructional” in combination with “principle(s)”, “theory” and “design”. References lists from relevant publications were then consulted to find additional studies. Infographics were not always the direct subject of the research, given the lack of primary research in this field. However, findings that could be applied to infographic design were considered. Additional fields including health and science communication were also consulted. These fields have recently began researching the value of visual communication of complex information using infographics, so were valuable in establishing researched design guidelines. This divided the principle established in the literature review into 6 core subjects. Starting with those defined using human cognition theory, including: cognitive multimedia principles, and Gestalt principles. Then including more specific research looking at the 4 design elements of an infographic: layout, colour, typography, and graphics.

Publications were initially selected based on their abstract to judge if the content of the work could provide a principle applicable to the design of an infographic. The search resulted in the collection of 156 potentially relevant publications. These publications were then read in greater detail to extract a principle(s) from the results; considering the finding in the context of infographic design. Publications were excluded if the results were later found to be irrelevant to infographic design, deemed inconclusive or poorly supported, or if the conclusions were supported solely by practice-based theory. The literature review was later cross compared with the report by Lonsdale and Lonsdale (2019) who completed their own systematic review of information visualisation design principles. Any relevant research-based publications that fit the criteria were included in the literature review.

Consequently, 46 publications were excluded resulting in 110 publications used to establish the design principles. The findings from these publications were condensed and combined if appropriate. This resulted in the establishment of 84 infographic design principles (Appendix 1). The names and descriptions of the principles were either adapted from the source research, or created by the researcher to create a consistent explanation of the resulting design principles.

2.1.3. Focus of literature review

The literature review completed in this chapter was conducted to establish infographic design principles, that provide design process guidance to increase the chance of reaching an effective design solution. These principles are later applied and researched in the context of public health infographics as a method to optimise design effectiveness. The focus of the literature review, here, was on research-based guidelines, as practice-based guidelines have no empirical basis. To ensure relevance, only those principles that were applicable to the project definition of an infographic were consulted. Consultation of the current relevant research in this literature review resulted in 84 principles applicable to infographic design. These guidelines will be applied in the design of infographics, later in the project, to test if the effective application of design guidelines result in improved public health infographics (as measured by comprehension, accuracy and opinion).

Literature review – Definition of infographic design principles

2.2. Cognitive theory

The first field that was addressed in this literature review was human cognitive processing. This was to provide a framework on how infographics are processed and understood. As acknowledged in the introduction, infographics are both easier to understand and are more memorable than a basic written format (Lonsdale et al., 2019; Lunn et al., 2021). Theoretical models have been developed to understand how humans process and remember information. This theory is considered in the context of infographics to provide explanation as to why infographics appear both more memorable and easier to process, as well as investigate principles that can optimise this cognitive processing.

2.2.1. Working memory models

Atkinson and Shiffrin (1968) proposed one of the first working memory models, a theory known as the multi-store model (Figure 2.1). It suggests that human memory is split into 3 distinct stages: sensory memory, short-term memory (STM) and long-term memory (LTM). The sensory store processes all incoming sensory information and because of the large amount of incoming data it could only be held for a very limited amount of time (less than half a second). A small amount of information is then transferred to STM; but only if it has had attention given to it, and the rest of the information is disregarded. If the information in the STM was not rehearsed it would then deteriorate after 2 seconds (Miyake and Shah, 1999). Control processes, such as rehearsal and maintenance, ensures information is encoded and moves from the STM to the LTM for an indefinite time period (Yuan et al., 2006). This information could then be later accessed, given a related cognitive task. However, it has been criticised for being too simple and that the STM and LTM are not as mutually exclusive as the model suggests (Sternberg, 2009). Consequently, the theory was further developed by Baddeley and Hitch (1976) into the working memory model that appears to be the most widely supported (Yuan et al., 2006).

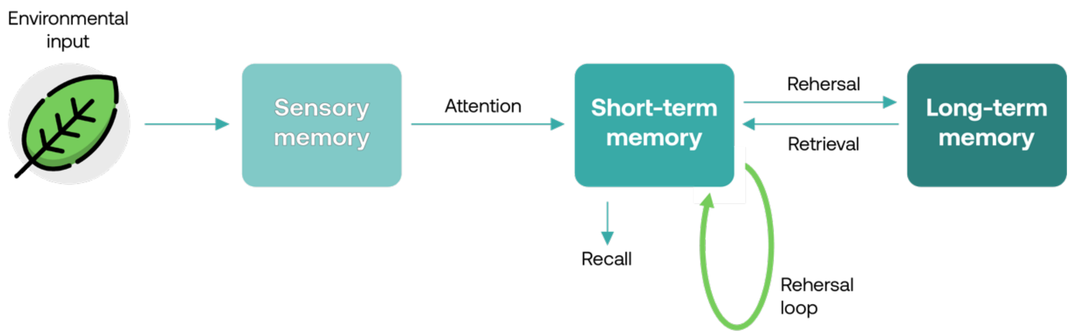


Figure 2.1 Displays the multistore memory model proposed by Atkinson and Shiffrin (1968) (p.113).

Baddely and Hitch (1974) further developed this theory, arguing that the multi-store model was too simple to explain to processes of short-term memory. The working memory model by Baddely and Hitch (1974) states that important sensory information is received by the central executive, a system allocates attention and the information to the 3 later systems (McLeod, 2008) (Figure 2.2). These 3 systems are known as the visuospatial sketchpad, the phonological loop and the episodic buffer. The visuospatial sketchpad briefly stores and processes all visual and spatial information. The phonological loop processes written or speech-based information and is composed of 2 parts: 1) the phonological loop that stores speech data; 2) the articulatory control process that interprets written information into a speech-based format, to allow it to enter the phonological store and to rehearse information (McLeod, 2008). The episodic buffer that acts as an intermediate between working memory and long-term memory, was later added to the model (Baddeley, 2000). Support for the theory exists in further experimental research (e.g. Baddeley and Hitch, 1976). The theory also supports the idea that visual and verbal information are processed separately.

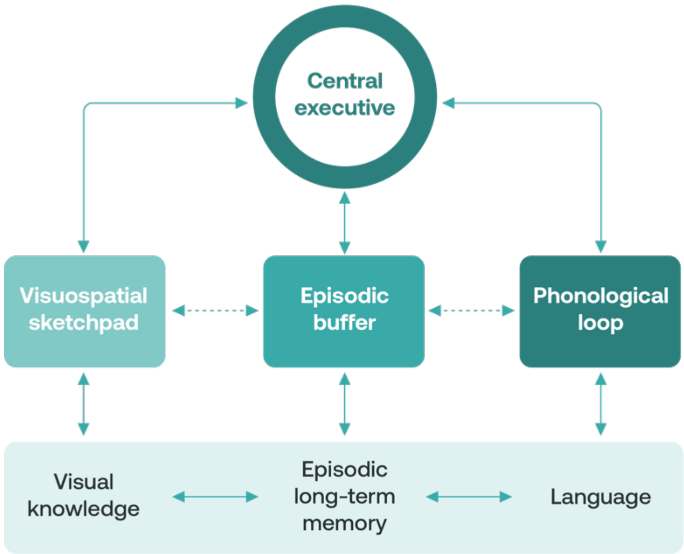


Figure 2.2 shows the working memory model proposed by Baddeley and Hitch (1974) (pp. 47–89).

2.2.2. Multimedia processing

Professor Richard Mayer has made great contributions to the field of psychology and multimedia learning. He describes multimedia as the combination of text and images, a definition that includes infographics. Thus, a large body of his research can be directly applied to the understanding of the cognitive processes behind infographics and their comprehension. Mayer popularised the Cognitive Theory of Multimedia Learning through his extensive work within the field; the theory states that we learn more deeply from a combination of text and images than just text alone (Mayer, 2005) and is widely accepted throughout cognitive psychology.

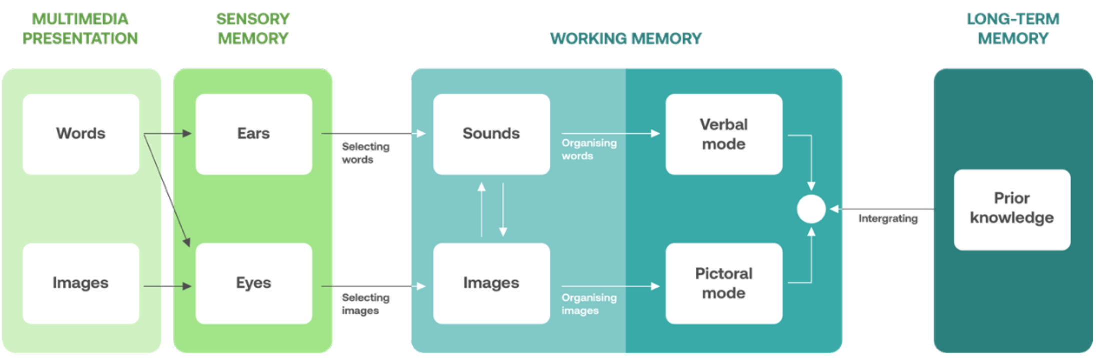


Figure 2.3 displays the model of multimedia learning, presented first by Mayer & Moreno (2003) (p.44).

Mayer developed the model of multimedia learning and presented it in their 2003 paper (Mayer and Moreno, 2003). It was developed in consideration of previous memory models but is specific to the processing of multimedia information. This model is especially applicable to infographic design as Mayer defines multimedia as learning from a combination of text and imagery. It is based on 3 assumptions originated from widely accepted theories on cognitive processing. The first known as the dual channel assumption, derived from dual-coding theory (Paivio, 1990) and the Theory of Working Memory (Baddeley, 1998). It states that humans process information through 2 varying channels; one processing visual information and the other processing verbal or auditory information. The second assumption is based on Cognitive Load Theory by Sweller (Sweller, 1988; Sweller, 1994). It proposes that a limited amount of information can be processed by both channels. The final theory is based on previous work by Mayer (Mayer, 1999; Mayer, 2002) as well as Wittrock's generative-learning theory (Wittrock, 1989); it says there must be a significant amount of cognitive processing within the channels for meaningful learning to occur. The main idea is that elements such as text and images are chosen and organised into a coherent structure. Thus, with both channels utilised learning potential can be maximised; the 2 channels separately process the 2 types of information in working memory. The user then integrates the visual and auditory/written information and applies it to prior knowledge, thus, promoting deeper learning – Figure 2.3.

In their publication, Mayer and Moreno (2003) consider the implications of the Cognitive Theory of Multimedia Learning. The risk of cognitive overload is recognised, where the demands required to process the information is higher than the user's cognitive capacity. It is said that multimedia learning can be lessened by overloading the user's cognitive potential. Thus, methods to reduce this overload are proposed. The authors define three types of cognitive processing: 1) Essential processing that involves all processes needed to make sense of the information; 2) Incidental processing that is non-essential to understanding; and 3) Representational processing that requires the user to briefly store information to make sense of another area of info (e.g. text and accompanying image). Methods for the reduction of cognitive overload are then proposed. Mayer goes on to review relevant literature on multimedia learning in book Multimedia Learning (Mayer, 2009). The large body of studies from the past 20 years were used to develop design principles. In total, 6 out of 9 principles were considered applicable to infographic design and are listed in Table 2.1. The 3 multimedia principles that were not considered were removed as they either referred to narration (e.g., for multimedia presentations or videos), or the principle referred to a specific teaching technique that could not be utilised in the context of an infographic.

Principle	Definition
Signalling	User learning is optimised when essential information is highlighted using cues that also signifies organisation.
Spacial continuity	User learning is optimised when images and the corresponding text are placed in close proximity rather than far apart.
Coherance	User learning is optimised when extraneous information is removed.
Pre-training	User learning is deeper when they receive pre-training on key information (or have prior knowledge).
Personalisation	User learning is optimised when text content is in a less formal, more conversational style.
Segmenting	User learning is optimised when information is segmented rather than one continuous list.

Table 2.1. displays the cognitive principles defined by Mayer (2009) in his publication on multimedia learning.

2.2.3. Information chunking

The concept of information chunking was first presented by Miller in 1956, where it was stated that working memory is limited and can only store a finite amount of information 'chunks'. Chunking is defined by the grouping of elements of information into an inter-associated unit, based on the information's meaning. Thus, it allows an increased amount of information to be encoded and reduces cognitive load (Patterson et al., 2014). Recent research has suggested the brain can store 3-5 meaningful information 'chunks' and can contain a potentially large amount of information (Gilchrist et al., 2008; Cowan, 2010). Patterson et al. (2014) applied the principle of chunking to information visualisation. They suggest that designers should create strong memory revival cues for the most relevant information, so chunking important information into a unit is beneficial. It can be achieved by grouping imagery within space, through selective use of colour, or through the application of Gestalt principles associated with grouping such as proximity, closure, and continuity. A study by Saariluoma and Sajaniemi (1989) explored the application of chunking information in the context of visual data on spreadsheets. It was recorded that simple information chunking, achieved through spatial organisation, significantly reduced the cognitive effort required to understand the data and optimised performance.

In brief, human memory can be considered to have 3 basic stages. These being sensory memory, working memory and long-term memory; with short-term memory storage being a function of working memory (Yuan et al., 2006). The sensory memory very briefly processes the vast amount of sensory information and only information that has attention directed to it is encoded and moves into the working memory (Sternberg, 2009). The working memory has finite storage capacity and can only store 3-5 chunks of information for a limited amount of time (Cowan, 2010). Here, the information is either discarded or transferred to the long-term memory through deeper processing when information is linked to prior knowledge or rehearsed. Figure 2.4 shows an overview of the current human memory model based on dual-processing. Though in reality the processes of memory are likely not as structured as this, the model acts as a simplified way to understand the process and how to optimise memory potential for desired information. Evidence of the theories effectiveness have also been proven in context, with evidence that their application can optimise information processing (Tetlan and Marschalek, 2016).

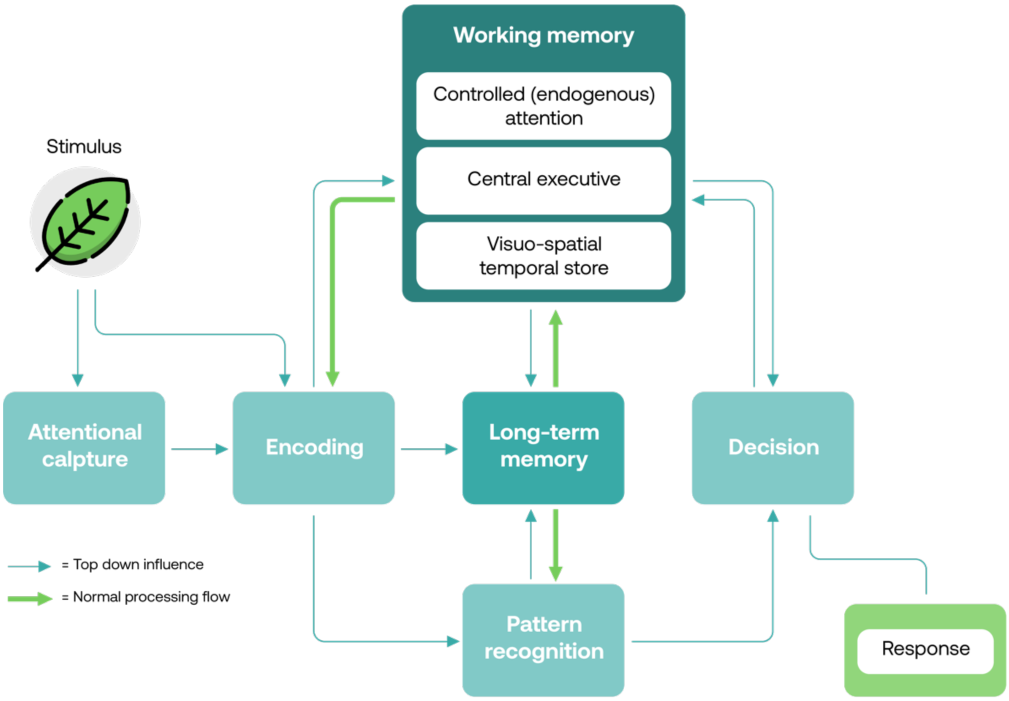


Figure 2.4 displays the current human memory model for information visualisation processing based on dual-processing theory, as proposed by Patterson et al. (2014) (p. 45).

2.2.4. Cognitive theory in context

The paper by Patterson et al. (2014) also further investigates the application of cognitive theory to information visualisation and proposes 4 other principles applicable to infographics. The first they list relates to capturing exogenous attention, which is designing elements that subconsciously attract a user's attention to important areas of an infographic. Exogenous attention is automatically drawn by a stimulus, rather than being a conscious decision by the user. Effective colour application is a prime example of the utilisation of this principle. The authors acknowledge the existence of inattentional blindness (Simons, 2000), where a user's accidentally misses vital information, and advises that methods of attracting attention can prevent this.

The second principle addressed by Patterson et al. (2014) states that endogenous attention should be directed, and information appropriately organised to focus attention. Endogenous attention is defined as the voluntary attention of a user towards a stimulus

(Patterson et al., 2014). Therefore, it is suggested that information should be organised using visible cues that direct a user's attention, such as designing an arrow that leads to an area of important information. It also means that unnecessary cues should be removed allowing the user to focus attention only on relevant information.

Patterson et al. (2014) go on to suggest mental models should be addressed to aid user reasoning. A mental model is the user's personal representation of the information they are processing (Liu and Stasko, 2010). However, within the publication the definition and potential application of this principle is vague. Though the idea is deeper explored in a review by Liu and Stasko (2010), the practical application of mental models on infographic design are again insufficiently discussed; so was not included in the final list of infographic design principles.

Finally, it is stated that creating visualisations that have some of analogical familiarity with a user will create strong retrieval cues and establishing reasoning. An example is discussed in (Burkhard and Meier, 2005) where the authors adapted a Gantt chart to display the information in the style of a subway map. It was interpreted that the users previous understanding of subway maps allowed the work-based time scale information it represented to be both engaging and more easily understood. By directly linking the visualisation to something the user already has prior knowledge in, the information can be more optimally processed. This, however, may not always be possible or appropriate in every form of visualisation; though it is worth considering. Patterson et al. (2014) conclude by advising the designer to consider cognitive processes when designing visual information, in order to encourage higher-level cognitive functioning.

Later work by Tetlan and Marschalek (2016) also aimed to evaluate the cognitive processes that influence the understanding of visual information, and how this could impact the subsequent design process. Attention factors were reviewed that could influence a user's attention for information including: attentional capacity, split attention and cognitive overload; supplying additional support to principles presented by Mayer and Moreno (2003). Again, it was concluded that chunking information assists in information recall, as well as the recommendation to prevent overload of an area with information as it prevents the brain from efficiently processing sensory information. Additionally, it was identified that the creation of hierarchy within visual information designs optimise processing, leading to optimised learning. The principle of consistency is also presented by Bettman et al. (1986) in a publication regarding designing risk information, on product labels, with consideration for cognitive processes. It is recommended that common or repeated information should be consistently presented the same way, in terms of placement and appearance. The example from the paper being health warnings on a cleaning product label. By presenting repeating information with consistency, the user will know where to locate the information quickly.

Other principles not mentioned elsewhere include the limitation of choices, where it is said that providing too many visible choices can cause user difficultly making decisions (Hick, 1952). Important information should also reportedly be placed first to establish expectation and allow the user to better predict and understand subsequent information. Finally, to provide visual cue reminders allows users to recognise what information they are seeing when they are required to process multiple pieces of information. A recent review by Padilla et al. (2018) provides further evidence for the application of cognitive principles in visualisation design. They state that understanding of the underlying cognitive principles has evident benefits in optimising the design of information. Notable recommendations by the authors include the identification of important information and directing a user's attention here using visual encoding, supporting the publication by Patterson et al. (2014).

SUMMARY OF PRINCIPLES COLLECTED FROM THE LITERATURE REVIEW

Section 1. Cognitive principles:

1. Signal important information
Highlight the most importance information using visual cues to optimise user learning potential (Mayer, 2009).

2. Information chunking
Organise related information into meaningful 'chunks' to increase chance of the information being retained and reduce cognitive load (Miller, 1956; Mayer, 2009;

Patterson et al., 2014; Tetlan and Marschalek, 2016). These should be defined using visual tools such as white space, colour and application of the gestalt principles (Patterson et al., 2014).

3. Spatial continuity

User learning is optimised when images and the corresponding text are placed in close proximity rather than far apart (Mayer, 2009).

4. Cognitive overload

Prevent cognitive overload by preventing the display of too much information at once. This is applicable to both text and visual information meaning a design should be simple and clear (Mayer and Moreno, 2003; Patterson et al., 2014).

5. Unnecessary cues

Remove unnecessary visual cues to allow a user to focus their attention on the most important information (Patterson et al., 2014).

6. Attract exogenous attention

Exogenous attention is the unconscious attraction to a visual stimulus. Attract a user's attention to the most important areas of an infographic using visual cues such as colour (Patterson et al., 2014).

7. Attract endogenous attention

Endogenous attention is defined as the voluntary attention of a user towards a stimulus. Information should be organised using visible cues that direct a user's attention; such as designing an arrow that leads to an area of important information. (Patterson et al., 2014).

8. Familiar visual representation

By creating visuals that are similar to universally learned information, a user can better understand and memorise information as it is connected to their prior knowledge. An example being using familiar icons, such as male and female toilet signs. (Burkhard and Meier, 2005; Patterson et al., 2014).

9. Consider cognition

Understand user and tailor design based on the application of the information with consideration of cognitive processing (Patterson et al., 2014).

10. Create hierarchy

The creation of hierarchy within visual information designs optimise processing; leading to optimised learning (Tetlan and Marschalek, 2016).

11. Design consistency

Common or repeated information should be consistently presented the same way, in terms of placement and appearance to allow the under to locate the information quickly (Bettman et al., 1986).

12. Visible choice

Limit the number of visual choices available to streamline a design and the reading order, as too many choices difficultly (Hick, 1952).

13. Align information

Align information visualisation design with user thought patterns and task demands, through careful research into user perception (Padilla et al., 2018).

2.3. Gestalt Principles

Gestalt theory is a series of visual principles derived from 1920s German psychology, developed through work by Wolfgang Kohler, Max Wertheimer and Kurt Koffka (InteractionDesignFoundation, 2020). The principles were created to explain how people percept complex images, by seeing patterns and grouping elements. The application of graphic theory in visualising and communicating complex info has been considered an effective tool (Frankel and DePace, 2012; Estrada and Davis, 2015). Here, the 9 applicable principles and their use in infographic design are considered.

Research has been published in support of utilising these principles to reduce cognitive effort viewing visual information. Moore and Fitz (1993) applied 6 Gestalt principles to instructional material including: proximity, closure, symmetry, figure-ground, continuity, and similarity. They concluded that the consideration of these principles made the instructions clearer and more useful, and the theory more powerful than existing visual presentation guidelines. This was later replicated by Smith-Gratto and Fisher (1999) for instructional screen design, again utilising gestalt principles to improve the design and coming to a similar conclusion. Unfortunately, neither of the publications involved experimental research and therefore no evidence was provided to support their claims. Chang et al. (2002) undertook opinion-based testing on an original webpage after applying eleven of the principles to webpage information. Results were overwhelmingly positive for the redesigned material, suggesting theoretical application to design practice can optimise learning.

Some experimental evidence exists in support of Gestalt principles. Jin (2013) applied Gestalt theory, along with other visual communication guidelines, to digital text. Improvements were recorded on usability, text structure understanding, and the comprehension on the essential content, when compared to a control group. Application of the Gestalt law of similarity to bar and line graphs were also found to significantly improve performance (Ali and Peebles, 2013). Preliminary results by Koch and Oulasvirta (2016) also suggest that the application of four Gestalt laws presents benefits to hierarchal structuring of webpages. Additionally, they acknowledge the challenge of the effective use of the theory because of the multitude of design features available and relative absence of contextual approaches.

The use of Gestalt principles on infographics were also explored by de Brouwer (2014) in an eye-tracking experiment. Unfortunately, the tested infographics were poorly designed, not applying certain principles, suggesting a reason for the lack of positive results. The lack of empirical evidence for the principles may be explained by the relative age of the theories, as these might be considered fact due to their practise-led application, as well as the large amount of time they have existed. However, from a review of the literature it is clear that more empirical research needs to be conducted to explore whether applying the theory leads to an effective design solution, and the potential benefit to user performance.

In the Gestalt principles discussed in this literature review, each principle is accompanied by a good and poor example of practice collected by the researcher, where the good example effectively utilises the listed principle. The poor example also uses the principle but has done so ineffectively, for example an infographic may apply the rule of proximity by placing related elements together but by also placing separate elements too close the potential benefit is diminished. The examples may also apply multiple Gestalt principles, as is common, but for the sake of the example only the effectiveness of the discussed principle is considered. The application of the principles was based on the opinion of the researcher, as well as an information design research expert. The examples were used included only to illustrate the use of the Gestalt principles, and not in later research or principle definition. These examples were located online through a search engine and through websites of fields that frequently use information visualisations, such as online newspapers.

2.3.1. Proximity

Proximity states that objects that are closer together are interpreted as being related (Graham, 2008; Ali and Peebles, 2013). The closer together objects are, the closer their relationship is thought to be (Chang et al., 2002). Objects in a close arrangement form a group association; this can happen when objects are closer to each other than any other objects are. Application of this in infographic design is benefitted by the manipulation of white space to create clear areas of grouped information.

Figure 2.5, the infographic includes many sections of information, but these are effectively organised by utilising the proximity principle. Related information is grouped together, as can be observed where an image and the accompanying text are placed in close proximity. There is an appropriate amount of white space between the groups to ensure these chunks are an independent section of information. These make up larger sections of information that are again defined as a group by the space between the sections. Figure 2.6 attempts to utilise proximity but has not been successfully applied. There is not enough space between the different sections of information. Thus, the initial perception is that all the information is part of one group, making it hard to understand the logic and order of the infographic. For example, information for Section 3 is in the middle of information that is for Section 2.

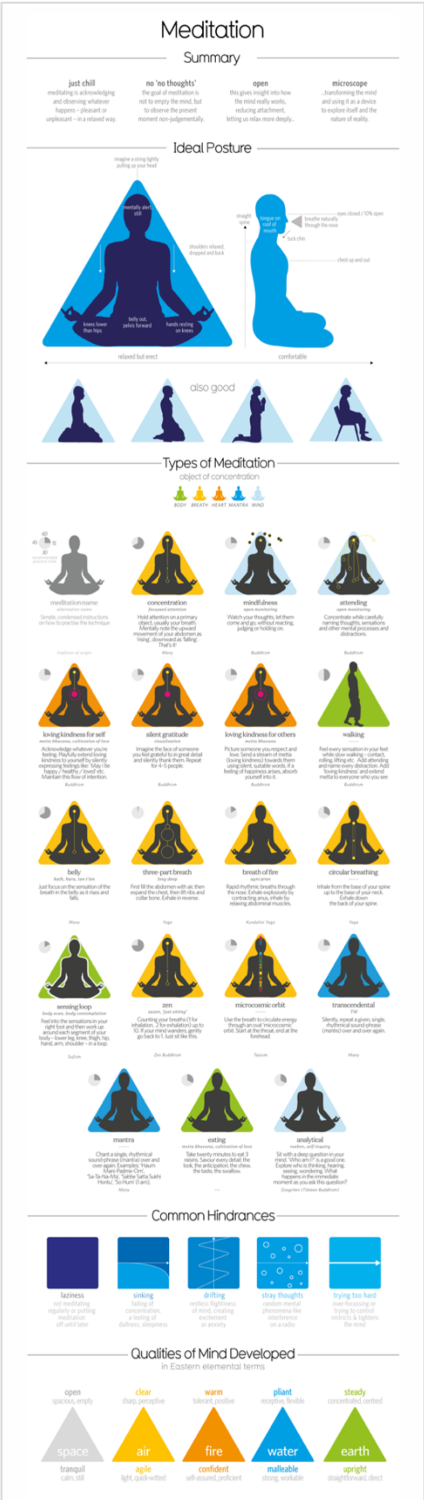


Figure 2.5 Example of good practice in applying proximity principle (InformationIsBeautiful, 2019c).

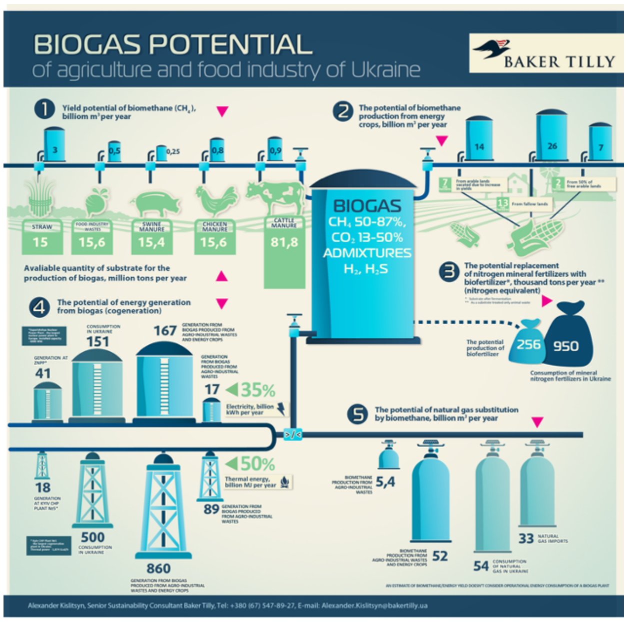


Figure 2.6 Example of poor practice in applying proximity principle (Visually, 2019a).

2.3.2. Similarity

The more visual characteristics objects share, the more likely they are to be perceived as being related (Ali and Peebles, 2013). This can be achieved by matching: colour, shape, size, value, etc (Graham, 2008). Colour has priority over shape for grouping, so colour should be the primary means to display information connection (Gkogka, 2018). Consequently, an element can be emphasised by being dissimilar from all others.

Figure 2.7 uses both shape and colour to express the relationship between the information. All the years have an image of the USA, showing that the infographic is displaying a progression of data from year to year on the same country. Colour is then used consistently to describe the type of natural disaster, allowing the user to both understand the data and easily compare. Figure 2.8 also uses colour relate information. However, there is great inconsistency between the 3 base colours and what is displayed on the map, making it difficult to understand. Only closer inspection reveals that the colour has been layered, but this practise results in loss of all colour similarity, so any connection is difficult to understand.

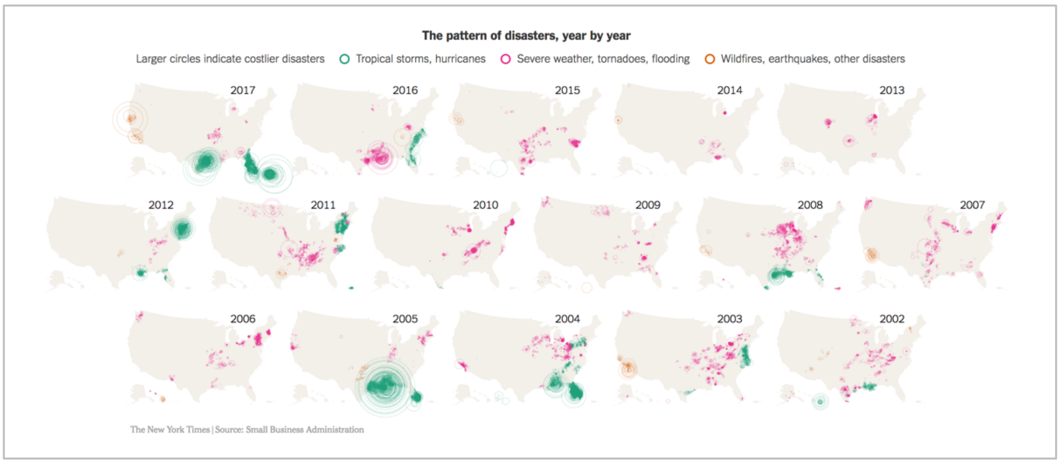


Figure 2.7 Example of good practice in applying similarity principle (TheNewYorkTimes, 2018b).

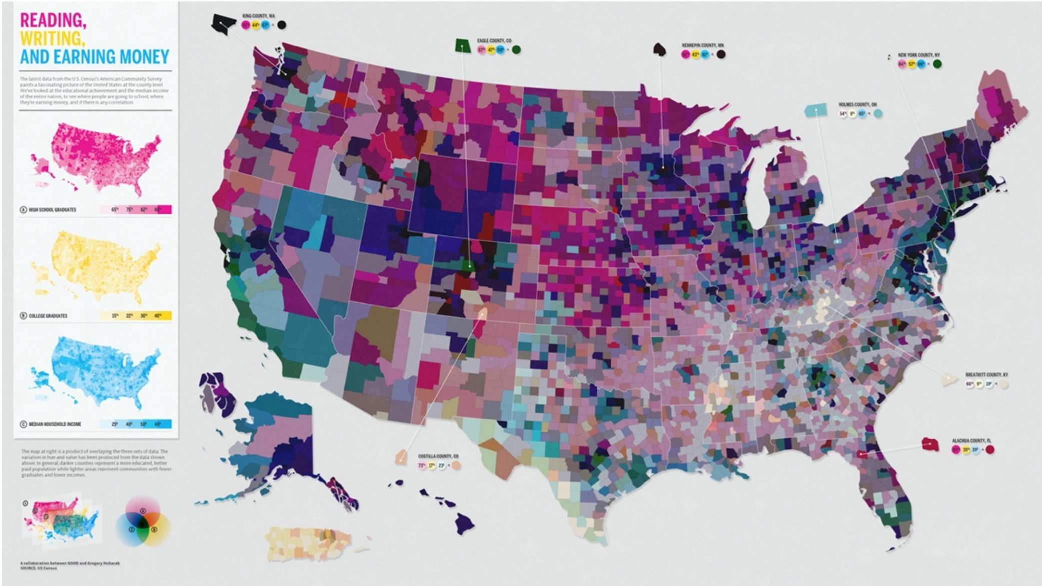


Figure 2.8 Example of poor practice in applying similarity principle (BusinessInsider, 2012).

2.3.3. Simplicity

Reduction in the cognitive load of a user when processing information visualisation makes the information easier to understand (Korpela, 2016). Application of this suggests simplifying graphic information and can be achieved through a reduction of visual clutter, colour, and variation in type size/style. Complex graphics may lead to unintended interpretation (Chang et al., 2002).

Figure 2.9 is very simple in its design, using a single hue with 2 colour value variation, circle shapes and a simple white background with black text. The lack of visual clutter allows the information to be quickly understood and the meaning obvious. The simple nature is also appropriate for the macabre subject of the infographic, emphasising the disturbing message the data conveys. Figure 2.10 has an overload of information making it appear cluttered. The visual complexity and dark colour palette result in an unattractive and inaccessible visualisation.

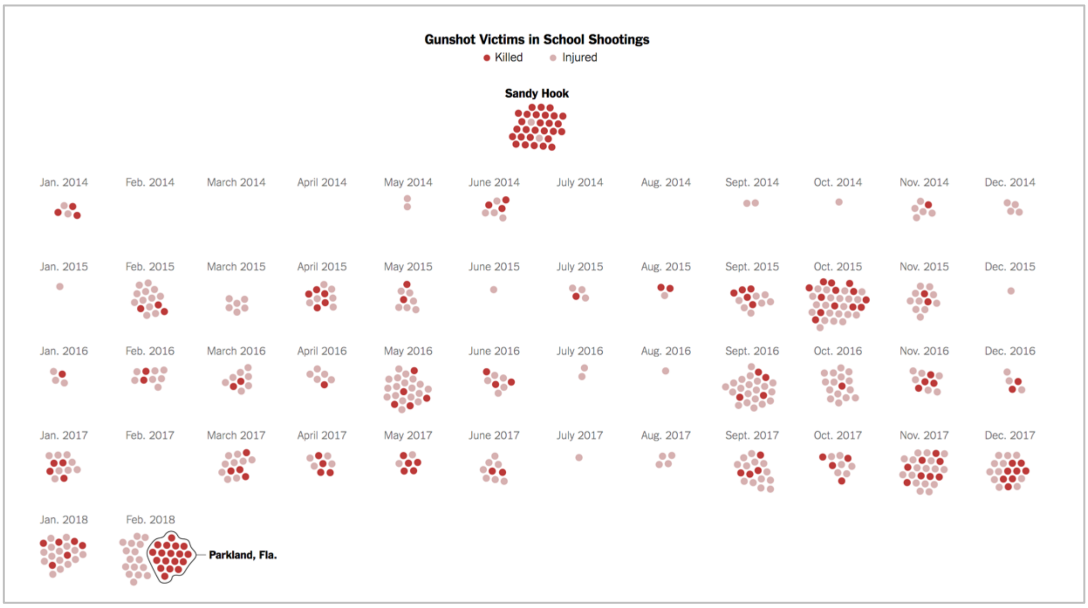


Figure 2.9 Example of good practice in applying simplicity principle (TheNewYorkTimes, 2018a).

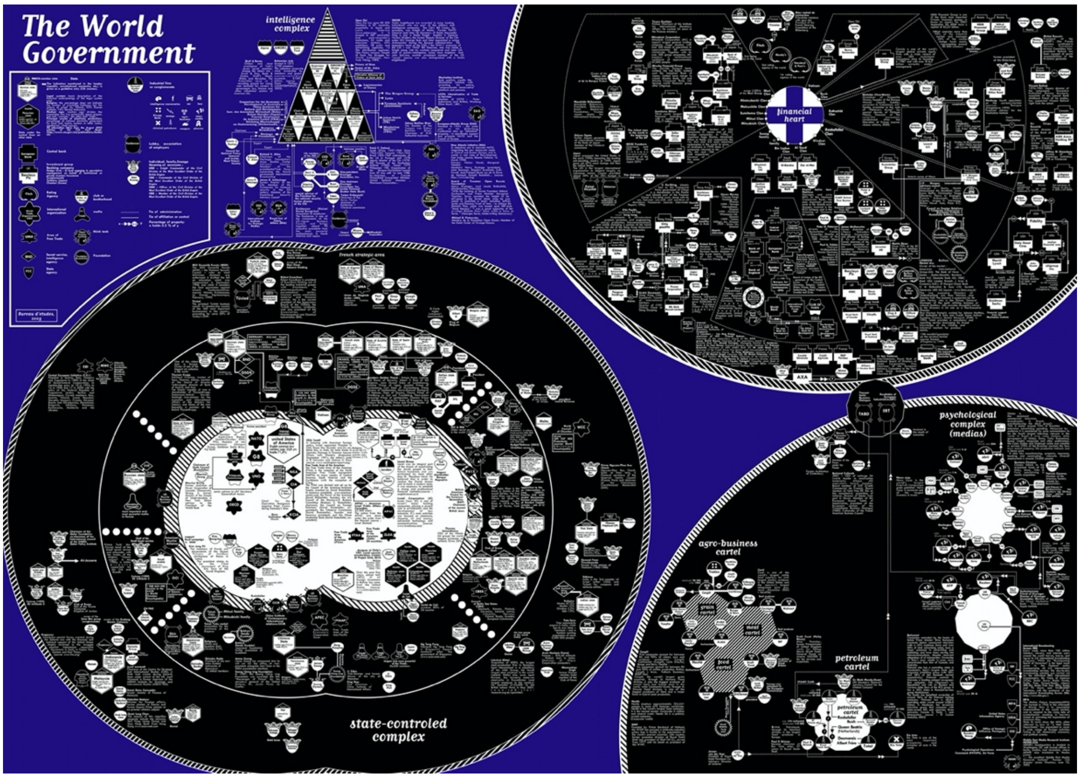


Figure 2.10 Example of poor practice in applying simplicity principle (NOW, 2019).

3.3.4. Enclosure

Closely related to the law of closure, the principle of enclosure can allow a user to understand information as belonging to a group when it is enclosed (Meeks, 2019). Enclosure can be achieved by creating boundaries around information by using block colour or lines to make a border. This helps to both organise information and define hierarchy and is especially useful in an infographic containing a large amount of text-based information.

Figure 2.11 effectively uses colour to enclose information to show it is grouped, the infographic is particularly effective as enclosures are layered showing groups within larger group. Figure 2.12 ineffectively uses enclosure to define every single section of information. Not only has this been poorly aligned, leading to an unattractive appearance, as the overuse of enclosure leads to a cluttered infographic. This can also make information harder to locate.

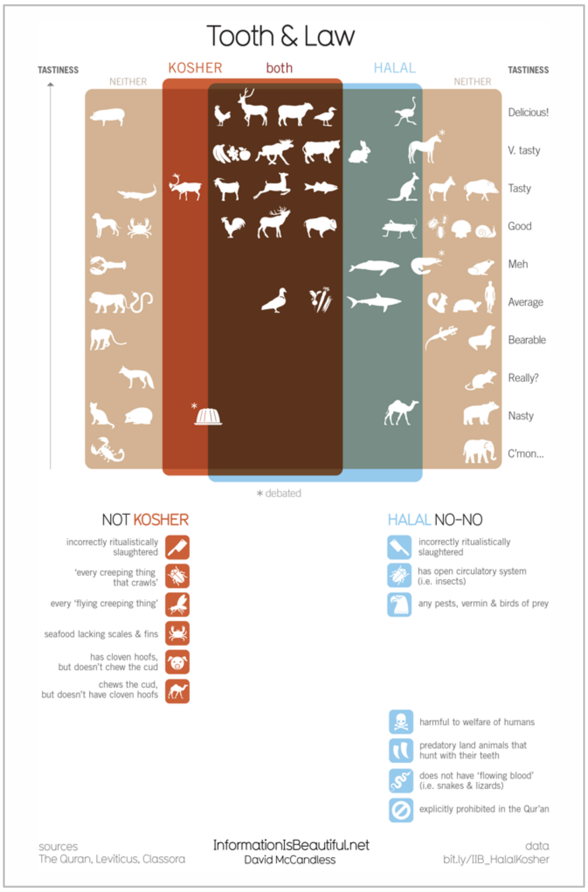


Figure 2.11 Example of good practice in applying enclosure principle (InformationIsBeautiful, 2018)

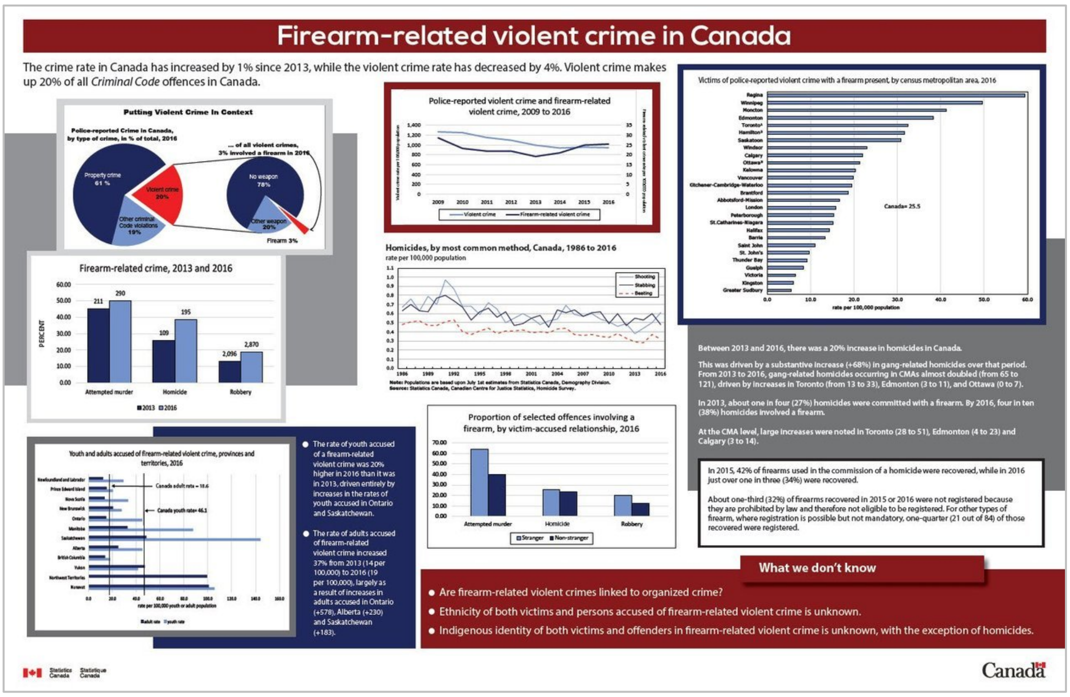
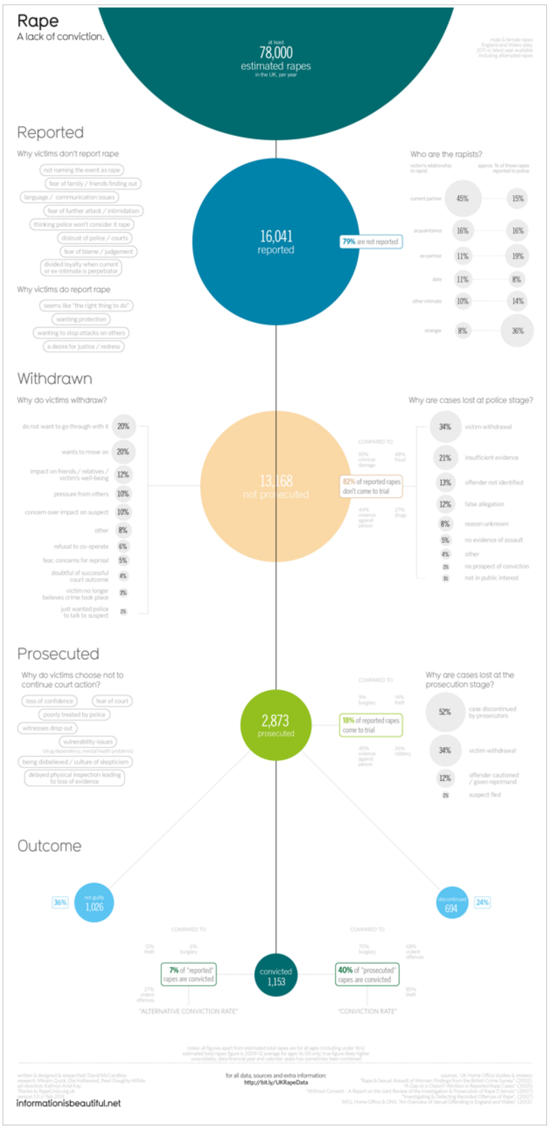


Figure 2.12 Example of poor practice in applying enclosure principle (StatisticsCanada, 2019).

2.3.5. Continuity

This principle proposes that once a user's eye is following a path they will continue to follow it until reaching another object, even if the shape or line ends, choosing to follow the smoothest line (Graham, 2008). It can be useful in guiding the users through a design and towards area of intended focus or leading from one object to the next (Gkogka, 2018). An example can be the use of an arrow to direct between image and text.

Figure 2.13 uses the continuity principle by designing a single line from the top of the infographic to the end, allowing the user to understand the natural order from the top to bottom. Lighter lines leading from the main line show alternative outcomes, the lighter colour signifying the less important outcomes. Figure 2.14 also uses lines to display the progression of the infographic, relating names to drinks. However, the sense of continuity is vastly reduced by the complex line design requiring great effort to follow to the related information. The basic comprehension of the infographic has been compromised in favour of aesthetic appeal.



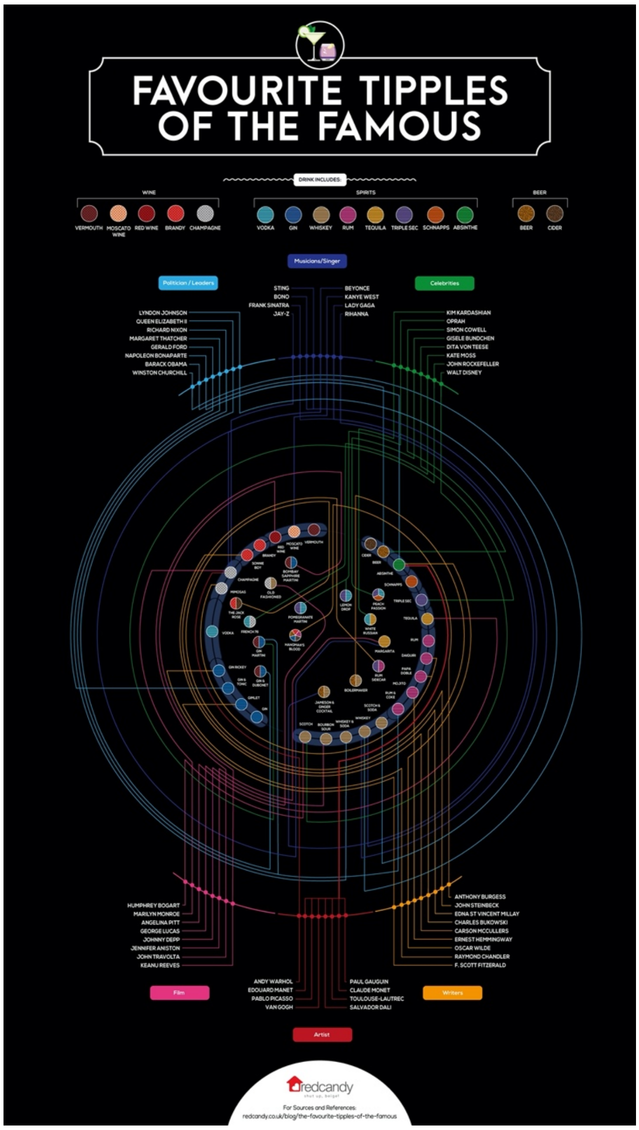


Figure 2.13 Example of good practice in applying continuity principle (InformationIsBeautiful, 2019b).

Figure 2.14 Example of poor practice in applying continuity principle (Visually, 2019b).

2.3.6. Figure/foreground

The human brain processes contrasting imagery as being in either the foreground or background, with the foreground being of greater importance (Korpela, 2016). Generally, the larger area is interpreted as the background and the smaller area the foreground. The use of a lighter or darker colour can also affect this. It is important to create enough contrast between foreground and background elements to optimise visual legibility (Korpela, 2016).

Figure 2.15 effectively uses contrasting colour to establish foreground information and a softer background to both emphasise the foreground imagery and represent water. Fish silhouettes effectively represent the information, and the high colour contrast between the orange foreground and blue background in the 'NO' section also highlights this data as being of greatest importance on the infographic. Figure 2.16 uses figure and foreground in a similar way to create imagery to represent information. Unfortunately, the textured background and the low contrast between background foreground colour makes it difficult to distinguish what information is most important. The lack of contrast also reduces text legibility.

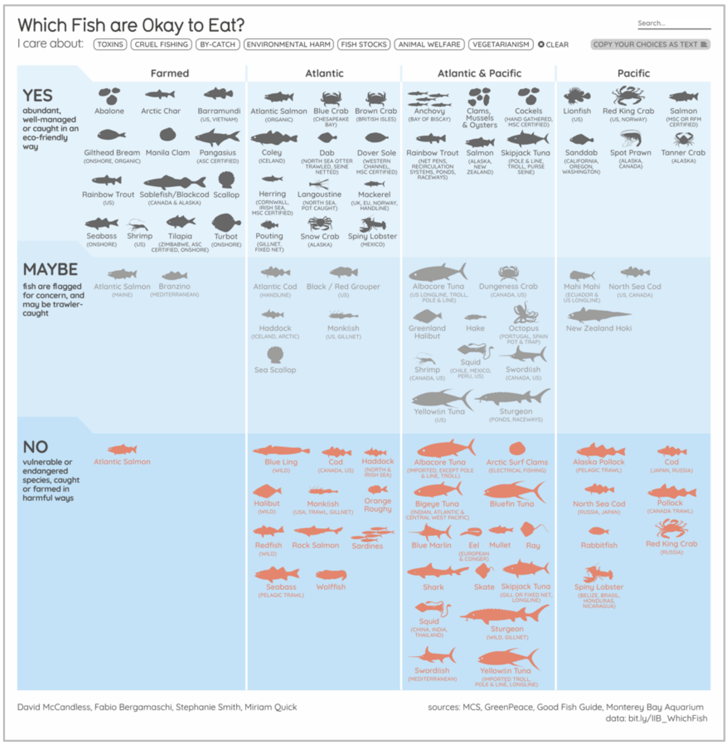


Figure 2.15 Example of good practice in applying figure principle (InformationIsBeautiful, 2019d).

Figure 2.16 Example of poor practice in applying figure/foreground principle (Visually, 2019c).

2.3.7. Symmetry

Symmetry is visually appealing and objects that are symmetrically aligned can be interpreted as being related (Gkogka, 2018). If a design is largely symmetrical, adding an asymmetrical element can focus a user's attention on it. Smith-Gratto and Fisher (1999) state that information should be displayed with visual balance, or a user may view it as incomplete. It is suggested that careful use of both symmetry and purposeful asymmetry is best.

Figure 2.17 creates an attractive visualisation, in part, by using multiple symmetrical elements. By arranging the icons symmetrically around the 4 images, in combination with colour relation, it is clear which icons are representing which name. The overall symmetrical appearance also makes the infographic look balanced and engaging. Figure 2.18 fails to utilise the principle of symmetry to increase visual appeal. By making every section the same size it makes it appear that every section is equivalent, when in reality the data values state otherwise. The 19 total sections also seem to have no correlation with the sixty second stopwatch the design is based upon.

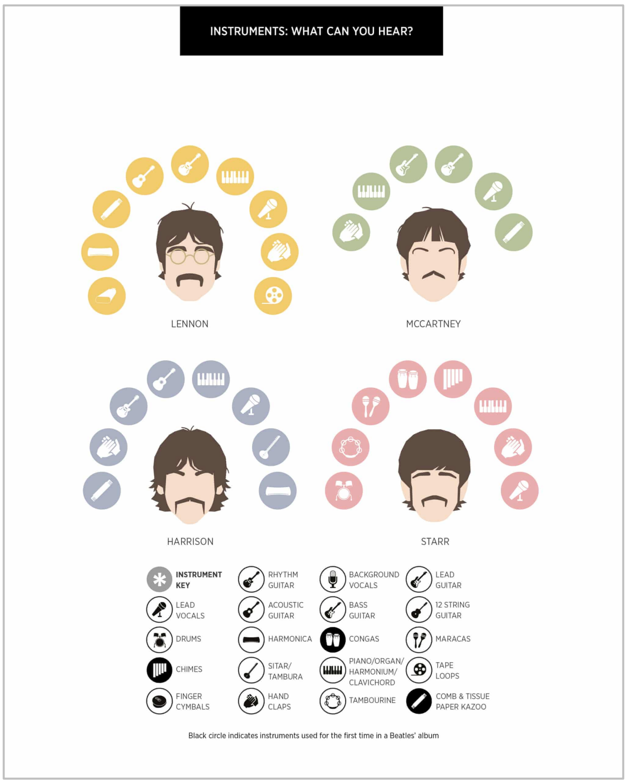


Figure 2.17 Example of good practice in applying symmetry principle (TheGuardian, 2016).

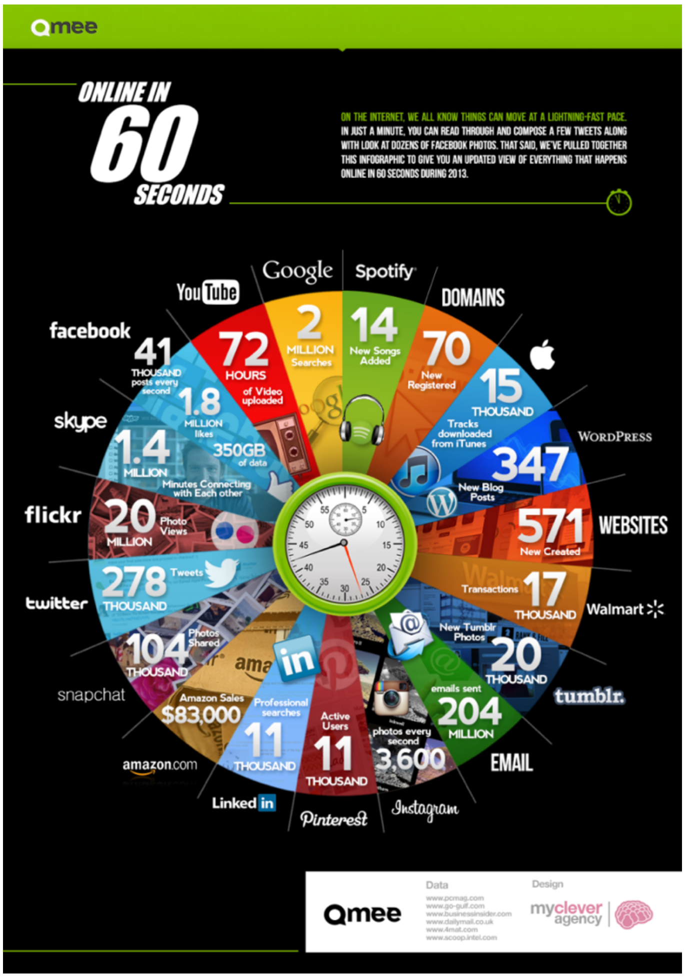


Figure 2.18 Example of poor practice in applying symmetry principle (MyCleverAgency, 2013).

2.3.8. Focal point

A focal point, or an element purposefully different to those surrounding it, attracts a user's attention (Korpela, 2016). Colour, size, and shape can be varied to create a focal point. This may be appropriate in infographic design to emphasise information of the highest importance (Chang et al., 2002). Another appropriate application is to emphasise a specific data value in a chart.

Figure 2.19 clearly emphasises the most important information on the infographic by using colour. The white background makes this stand out even more, creating obvious focal points of important information throughout the design. Figure 2.20 ineffectively utilises the principles and applies colour and size variation too frequently. Resulting in every area of information being emphasised and eliminating any specific focal points

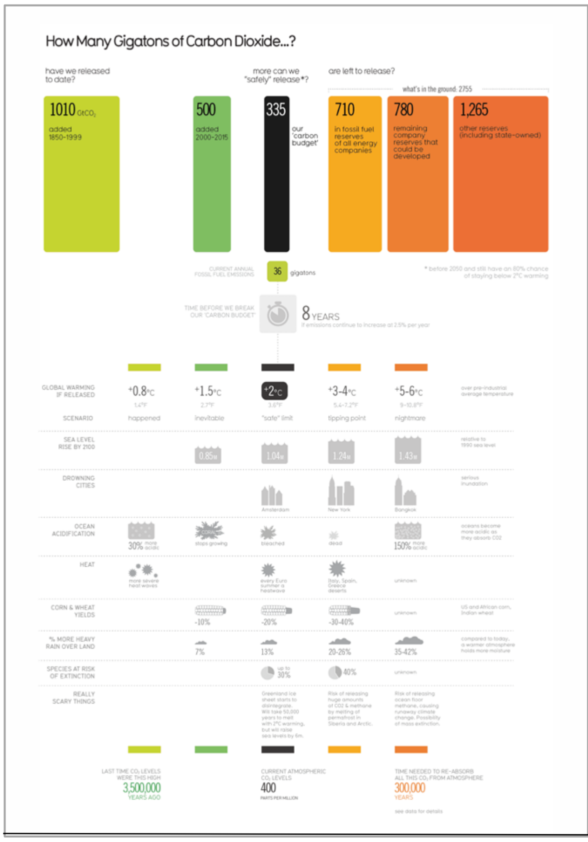


Figure 2.19 Example of good practice in applying focal point principle (InformationIsBeautiful, 2019a).

Figure 2.20 Example of poor practice in applying focal point principle (MediaMolecule, 2019).

2.3.9. Connectedness

Connectedness serves as a sub-category of the law of similarity that allows a user to interpret information as being grouped. Information or data points can be connected using elements, such as direct lines or frames, between areas of visual information that leads to the interpretation of the elements belonging to a group (Ali and Peebles, 2013; InteractionDesignFoundation, 2020). This principle is especially applicable to charts to connect related data points.

Figure 2.21 is a subway map of Washington DC that effectively uses 5 coloured lines to show singular train lines. The simplified design and basic colour palette make it easy to understand that stations within the line are connected. Figure 2.22 also uses connectedness in a similar way; by connecting related data with a colour coded line. However, the complexity and overuse of colour hues results in a confusing design. The lines on the chart, though aiming to visualise trends, does to achieve this and the trends are lost among the sheer number of coloured lines on the chart.

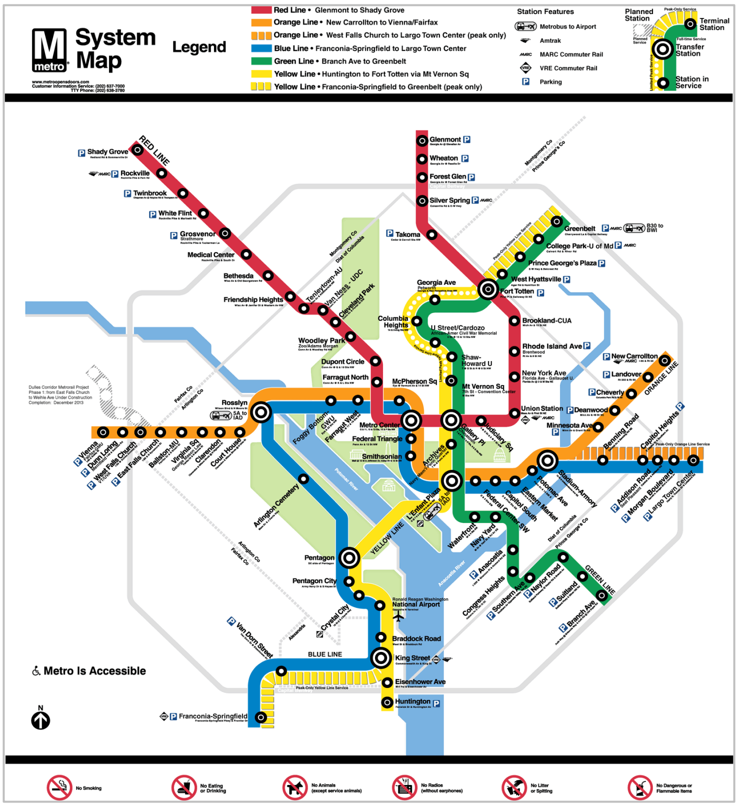


Figure 2.21 Example of good practice in applying connectedness principle (Metro, 2019).

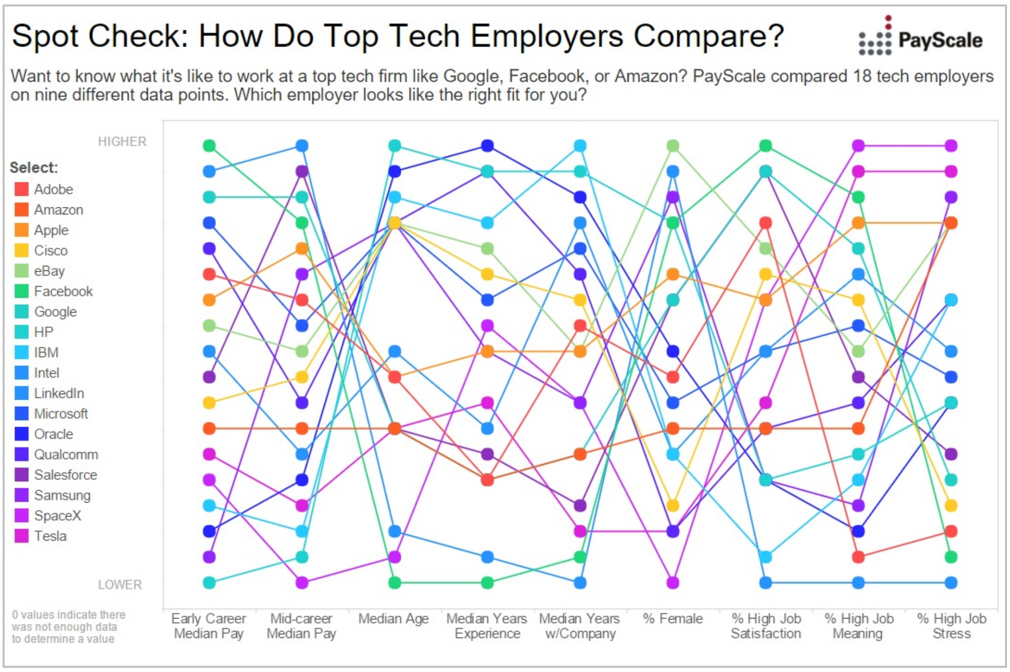


Figure 2.22 Example of poor practice in applying connectedness principle (PayScale, 2019).

SUMMARY OF PRINCIPLES COLLECTED FROM THE LITERATURE REVIEW

Section 3. Gestalt principles:

14. Proximity

Place related objects (e.g., image and explanatory text) closer together to allow a user to interpret them as being grouped.

15. Similarity

Make objects more visually similar if they are related. This can be done by matching: colour, shape, size, value, etc; colour has the greatest priority.

16. Simplicity

Reduce a user's cognitive load when reading infographics to make them both easier to understand and more accessible (Mayer, 2009). This can be done by keeping the design simple and reducing unnecessary visual clutter.

17. Enclosure

Information can be shown to be related by enclosing it using an outline or blocks of colour. This helps to organise and define hierarchy.

18. Continuity

Once a user's eye is following a path, they will continue to follow it until reaching another object, even if the shape or line ends. This can be utilised to lead a user through the intended reading direction of an infographic by using arrows and lines between one section to the next.

19. Figure/foreground

The human brain processes contrasting imagery as being in either the foreground or background, with the foreground being of greater importance. Create enough contrast between foreground and background elements to optimise visual legibility.

20. Symmetry

Symmetry is visually appealing to a user and objects that are symmetrically aligned can also be interpreted as being related. If a design is largely symmetrical, adding an asymmetrical element can focus a user's attention on it.

21. Focal point

Ensure the design has a clear focal point(s) to emphasise the information of highest importance. Colour, size, and shape can be varied to create a focal point.

22. Connectedness

Information or data points can be connected using elements, such as direct lines or frames, between areas of visual information. Use arrows or lines to connect related data points.

2.4. Typographic design

Typeface is one of the most essential elements of information communication, as text often conveys most of the information or provides explanation of the accompanying visual graphic. There has been a large amount of research exploring typographic design in print and, comparatively, less research on information presented on screen; despite the extensive use (Ling and van Schaik, 2007) and equal legibility (Singer and Alexander, 2017a; Singer and Alexander, 2017b). Though recently, digital typographic research has become more common, likely due to the widespread display of typeface on a screen-based format (e.g., computers, mobile phones). There remains some widely accepted typographic research concepts that has only taken place in a printed text context, however, it has been acknowledged that the findings of printed typographic research are not necessarily transferrable to screen (Kolers et al., 1981; Dillon, 1992; Dyson, 2004). The focus of the thesis is on screen-based information, though as discussed, some important typographic design research has not been replicated using digital typography. Consequently, more recent digital typographic research will take priority, and print based research will be consulted in subjects yet to be explored digitally.

Previous research from roughly 30 years ago found that reading rate is slower from CTR monitors than from print (e.g., Gould and Grischkowsky, 1984). Gould et al. (1987) summarised the research from ten experiments and determined that this is due to multiple factors, the most likely being the poorer image quality of the characters. Recent technology has likely minimised this discrepancy through technological evolution; resulting in much higher quality screen resolutions than were available 30 years ago. As such, recent research has found no difference in reading speed from modern screens compared to paper (e.g. Dündar and Akçayır, 2012; Hermena et al., 2017). Chen and Catrambone (2015) and Singer and Alexander (2017a) found no significant difference in text comprehension or reading performance between screen and print. Contradictory evidence stating print results in better comprehension does exist (Mangen et al., 2013), but the majority of recent research suggest there is no difference. The review by Singer and Alexander (2017b) examined 36 studies, concluding there is little difference in comprehension between the two mediums. The idea that text is more legible in print is no longer based on evidence, therefore justifying screen-based infographics as an appropriate method of text communication.

2.4.1. Elements of type

Figure 2.23 shows the meaning of 'x-height' when referred to in typographic design.

The first section will explore variation in the elements that create a typeface, such as x-height and serif or sans-serif, and what medium they were designed for. X-height is literal in its definition and refers to the height of the letter 'x' within a typeface (Figure 2.23). It is considered a relative unit of measurement as a baseline height for lowercase letters, and its comparative height can vary depending on the chosen typeface (Poulton, 1972; cited in Lonsdale, 2014;). Poulton (1972) argues that x-height is a better determinate of a typefaces size compared to any other characteristic. Serif and sans-serif is another important typographic design element. A serif refers the decorative line elements that adorn the ends of the letter – Figure 2.24 (Tselentis et al., 2012, p.150). Typically, these are considered a more traditional style. In a sans serif typeface this decorative element is completely removed to create a simpler font (Tselentis et al., 2012, p.166). This style of typeface is a more contemporary development and may be more appropriate for modern infographic design. The image below illustrates the clear differences between these styles of typeface.

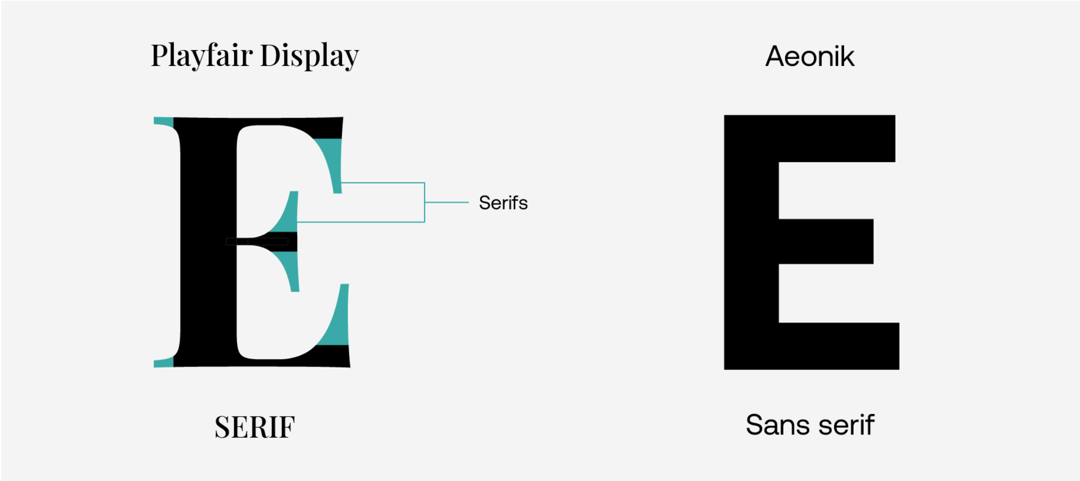


Figure 2.24 Displays the difference between a serif and sans-serif typeface.

Practise-based theory recommends that a designer should not use too many different typefaces to prevent it from appearing overwhelming or cluttered. Instead, typeface families should be limited to 2 or 3 in a single design; a rule now considered fundamental in the field of graphic design (e.g., Saltz, 2009; Babish, 2017). Additionally, if multiple typefaces are chosen they should be complimentary but distinctly different from one another to allow them to be distinguishable (Tselentis et al., 2012, p.232).

2.4.2. Type style

Text legibility should take priority for an information designer. Therefore, the chosen typeface should have a simple design that does not include design elements that might draw unnecessary attention or reduce the legibility of the information (Black, 1990; Hartley, 1994; Hartley, 2004; cited in Lonsdale, 2014). As long as a typeface is simple, there appears to be minimal differences in legibility between appropriate typefaces (Bernard et al., 2001; Lonsdale, 2014). However, when displaying text on screen some evidence supports using sans-serif and type designed specifically for screen, as is reviewed below.

Pušnik et al. (2016a) published a study in 2016 finding that upper case letters displaying a short title were recognised faster than lowercase on screen. Continuing from this research, they investigated if this effect was because of the increased size of uppercase letters or the character structure itself (Pušnik et al., 2016b). This was done by increasing the x-height of lowercase letters to match that of upper case. They found no significant difference in recognition speed across four of the five typefaces tested when comparing upper and lowercase. Only the typeface Calibri showed significant improvements in recognition when displayed as upper compared to lowercase, with Calibri also being the fastest recognised of all the tested typefaces. The researchers suggested that the curved edges and more 'open' style of the typeface may increase legibility. So, selecting a more 'open' typeface, such as Calibri, over a more 'static' typeface, such as Swiss 721, may be useful if title recognition is of great importance. However, the subjectivity of selecting an 'open' typeface meant this was not included in the final typographic principle list. The validity of this research on realistic title lengths is unclear given titles tested were only 3 letters long. However, the research clearly demonstrates that titles with larger text are recognised faster, promoting the use of larger type sizes on titles.

Previous research by Tinker and Paterson (1942) in print text design has explored the legibility of uppercase and lowercase text. Unfortunately, this has yet to be applied to online text displays so here an assumption is made that the research findings are transferable. Tinker and Paterson observed lowercase was read faster than uppercase text in 3 different experiments (Tinker and Paterson, 1928; Tinker and Paterson, 1942; Tinker, 1955; cited in Lonsdale, 2014); also observing a preference for lowercase text (Tinker and Paterson, 1942). Though it may seem like common sense, the publications by Tinker and Paterson may have influenced the common idea that lowercase text is optimal.

In screen-displayed text there is some evidence that sans-serif type designed specifically for screen may be better in digital mediums. An eye-tracking study compared a typeface designed for print (Times New Roman) versus one designed for screen (Verdana) (Hojjati and Muniandy, 2014); finding the readability of Verdana to be significantly better. The authors suggest this may be due to the type's simple design with a high x-height, purposefully designed width to enhance readability, and the lack of contact between letters to optimise their definition. However, a criticism of the study is all participants were international students and the potential result of non-native language ability was not considered by the authors.

Despite this, supporting results were observed in similar studies. Josephson (2008) who asked 6 participants to read text with Times New Roman or Arial, designed for print, or Georgia and Verdana designed for screen. Verdana was both preferred and performed best, suggesting a sans-serif typeface designed for screen is best when displaying text onscreen. However, the lack of significant difference and small sample size means the results are inconclusive. Chaparro *et al.* (2010) also recorded significantly better legibility of Verdana over Times New Roman, as measured by successful character identification following brief exposure. Additionally, Bernard *et al*. (2002) found Vendana as the most preferred of multiple typefaces.

The huge number of typefaces available makes it difficult to complete an experiment to find the most legible. However, the current research suggests there is minimal differences between the legibility of appropriate typefaces (Bernard et al., 2001;Lonsdale, 2014). Meaning that as long as a typeface is simple and free of extraneous features that attract attention to the typeface, rather than the text, then there is little evidence of differences between comprehension (Lonsdale, 2014). Other typographic features such as weight and size, are of greater importance. A designer should instead use a simple, clear typeface with a high x-height to ensure text is legible (Bernard et al., 2003; Amdur, 2007).

2.4.3. Serif vs Sans-serif

In the past it has been proposed that serif fonts are less suitable onscreen use because the resolution may not allow for rendering of the finer details displayed in a serif typeface, thus, reducing legibility (Byran, 1996). However, recent advances in technology resulting in higher resolution screens may have negated the potential negative effects (Ali et al., 2013). The current research conclusions when comparing serif and sans-serif readability onscreen are mixed.

The eye tracking studies previously discussed (Bernard et al., 2001; Josephson, 2008; Chaparro et al., 2010; Hojjati and Muniandy, 2014) found better legibility for the sans-serif typeface Verdana over the serif Times New Roman. Preferences were also described in favour of a sans-serif font. Bernard et al. (2003) and Banerjee et al. (2011) found no differences in readability but observed preference for sans-serif font. Multiple instances of user preference towards sans-serif have also been observed, despite the authors finding no significant difference in readability (e.g., Bernard et al., 2003; Ling and Van Schaik, 2006; Banerjee et al., 2011). However, a significant advantage in word recognition speed when using a sans-serif typeface, over serif, have too been shown through experimental research (Moret-Tatay and Perea, 2011).

Conversely, preferences for serif fonts in certain contexts, such as scientific abstracts and website interfaces, have also been recorded (Altaboli, 2013; Kaspar et al., 2015). It must be considered, however, that observed preferences from typefaces may be due to different design elements such as x-height and line thickness, rather than just the presence or absence of serifs. Ali et al. (2013) investigated differences in readability between serif and sans-serif typeface for web-based text and found no differences. Bernard et al. (2003) likewise stated type style has no significant effect on reading efficiency. Research has also recorded no differences in legibility of the same typeface with the serifs present or absent (Arditi and Cho, 2005).

Though not indisputably supported, there is some suggestion that bodies of text displayed on screen should be displayed in sans-serif over a serif style. Overall, research seems to suggest that a sans-serif typeface is usually preferred and sometimes performs better than a serif typeface in a screen-based format.

2.4.4. Type size

In context of printed text, it has been recorded that type sizes of between 9 and 12 pt were found to be equally legible, when measured by speed of reading (Tinker, 1965; cited in Lonsdale, 2014). More recent research exploring type size on packaging also concluded that 9 to 12 pt was optimal (Fuchs et al., 2008). Results were mirrored in experimental research by Bernard et al. (2003) that displayed 8 of the most popular online fonts on screen. They concluded that type size has no significant effect on reading efficiency between size 10, 12 and 14; although, size 12 was read faster than size 10 (Bernard et al., 2003). Eye-tracking data also supports this idea, finding no significant difference in reading speed between size 10, 12 and 14 point typefaces (Beymer et al., 2008). Franken et al. (2015) also recorded that reading speed does not decrease as size increases even in larger sizes up to 20 and 24, suggesting these larger type sizes are still viable for infographic titles if appropriate for the design.

An extensive review of typography literature by Lonsdale (2014) concludes that size 9 to 12 pt typeface is most appropriate to optimise text comprehension. However, it is acknowledged that the style of typeface can have an effect on the actual size of the displayed text; where a text with a larger x-height should be considered can be displayed at a smaller size without compromising legibility (Schriver, 1997). Unfortunately, screen-based research on type size is very limited. From the restricted research available it can be concluded that a reasonable type size should be utilised by designers in a range between 9 and 12 to display bodies of text.

2.4.5. Line length

Line length refers to the number of characters displayed in a single line can significantly affect the speed of text comprehension (e.g., Tinker, 1963; Dyson and Haselgrove, 2001). Founding print-based research by Tinker (1963) established that moderate line lengths resulted in both preference and faster reading compared to relatively short or long lines.

Again, the review by Lonsdale (2014) can be consulted for an effective summary of line length. In the format of print-based text, a moderate line length of roughly 60 to 70 characters is said to be optimal in displaying text information (Spencer, 1969; cited in Lonsdale, 2014). It is explained that difficulties from short line lengths are a result of the user having to change lines too frequently (Simmonds and Reynolds, 1994; cited in). In very long lengths the user can struggle as it is more difficult to correctly return to the start of the next line after reading a line, known as a return sweep (Carter et al., 1993; Schriver, 1997; cited in Lonsdale, 2014). A balance should be achieved where return sweeps are easy but not too frequent as to inhibit reading speed (Dyson, 2004).

Though not extensively researched, primary literature has also been conducted looking at line length onscreen. Dyson and Kipping (1998) stated that longer line lengths resulted in faster reading, suggesting the need to scroll more when using a shorter length slowed users. The researchers later investigated varying line lengths of 25, 55 or 100 characters per line (cpl) on-screen (Dyson and Haselgrove, 2001). Unfortunately, some key typographic principles were not applied when displaying the text by including small margins and justified text paragraphs. However, it was found that medium length of 55 cpl supports effective reading with highest level of information comprehension. Ling and Van Schaik (2006) expand upon this by looking more closely at the more realistic line lengths of 55, 70, 85 and 100 cpl. No significant differences in performance between the line lengths were found. However, the 55 and 70 cpl lengths were not only preferred but also resulted in more accurate information recognition.

Practise based theory also recommends that 60 to 65 cpl should be used to display text on webpages, with a lower limit of 40 characters (Davidov, 2002). Additionally, Shaikh (2005) found that comprehension is unaffected by line length between 35 and 95 characters per line when reading online information. Suggesting this is a viable range to display text with the optimal being between 55 to 70 cpl. The current research suggests using a moderate line length of between 55 to 70 cpl to optimise the reading of text-based information.

2.4.6. Text spacing and alignment

Interlinear spacing and text alignment both have an impact on the appearance of a body of text, and research has shown they may also influence legibility (e.g. Ling and van Schaik, 2007). Interlinear spacing refers to the amount of vertical distance between one baseline to the one beneath in a body of text (Tselentis et al., 2012). Text alignment is the positioning of text, inside a block of text, and where it lines up to an unseen axis to the left or right (Tselentis et al., 2012). They can also be centre-justified, where the sentence lines up both to the left and right, with additional letter spacing potentially added to make this possible. Lonsdale (2014) explains the effect of both interlinear spacing and alignment, referencing research by Gregory and Poulton (1970) who found that centre-justified text resulted in poorer performance in less able readers.

There is relatively little effective research on the effect of interlinear spacing and alignment in an onscreen format. Some recent research exists in the subject of traditional Chinese text spacing providing evidence of its effect (e.g., Chan and Ng, 2012; Chan et al., 2014; Huang et al., 2018b). However, it cannot be assumed that the findings of this research can be directly applied to English typographic design, due to the great variation visible in their written language structure.

Ling and van Schaik (2007) found supporting evidence for the use of increased line spacing, researching the English alphabet. They aimed to investigate the effect of line spacing and text alignment on visual search performance, as well as explore the users aesthetic rating of these typographic design variables. A total of 65 participants were asked to recognise the presence or absence of a hyperlink within a series of paragraphs and their accuracy and speed were recorded. Either left aligned or justified text were used, and within these groups either single, 1.5 or double line spacing. Although justified text was preferred, participants performed better with left aligned text. Visual search performance and accuracy was also significantly better with 1.5 or double spacing. The results suggest that online text should be left justified and utilising larger text spacing (1.5 or double). The authors also emphasise the benefit of displaying information in an uncluttered style, to optimise information searching and legibility. The lack of viable research in this area, however, may reduce the confidence in these conclusions.

SUMMARY OF PRINCIPLES COLLECTED FROM THE LITERATURE REVIEW
Section 4. Typographic design:

23. Number of typefaces
Typeface families should be limited to 2 or 3 in a single design (infographic) (e.g., Saltz, 2009; Babish, 2017; Murray et al., 2017).

24. Complimentary typefaces
If multiple typefaces are chosen they should be complimentary but distinctly different from one another to allow them to be distinguishable (Saltz, 2009).

25. Simple typeface

A simple typeface should be chosen that is simple that does not include design elements that might draw unnecessary attention or reduce the legibility of the information (Black, 1990; Hartley, 1994; Hartley, 2004).

26. Large x-height

Use a typeface with an appropriately large x-height to increase legibility when text is displayed smaller (Poulton, 1972; Pušnik et al., 2016b).

27. Capitalised letters

Avoid using uppercase type for sentences as they are read slower (Tinker and Paterson, 1928; Tinker and Paterson, 1942; Tinker, 1955)

28. Screen designed type

Use a typeface designed for screens when displaying information in that format, such as Verdana (Bernard et al., 2003; Chaparro et al., 2010; Hojjati and Muniandy, 2014).

29. Sans-serif typefaces

Use a sans serif typeface onscreen as it is preferred, and evidence exists suggesting it is more legible that serif typefaces (Josephson, 2008; Chaparro et al., 2010; Banerjee et al., 2011; Hojjati and Muniandy, 2014).

30. 9-12 pt Type size

Use a type size between 9-12 pt for the body of text (Tinker, 1965; Bernard et al., 2003; Beymer et al., 2008; Lonsdale, 2014).

31. 55-70 character line length

Use a moderate line length of roughly 55-70 characters per line when displaying block text information to optimise reading (Spencer, 1969; Dyson and Haselgrove, 2001; Ling and Van Schaik, 2006; Lonsdale, 2014).

32. Left text justification

Justify text to the left to optimise legibility of online text (Ling and Van Schaik, 2006).

33. 1.5-2 line spacing

Use line spacing of 1.5 or 2 to optimise the legibility in a block of text (Ling and Van Schaik, 2006).

34. Clear text style

Display text in a simple, uncluttered style to prioritise text readability (Bernard et al., 2003; Amdur, 2007).

2.5. Colour design

Colour is one of the most powerful elements in visual perception displaying an incomparable ability to capture attention (Pan, 2010). The cognitive requirements of processing colour are low and occurs subconsciously, emphasising its existence as one of the basic elements of visual perception (Treisman, 1986). It has the capability to convey both meaning and effect behavioural, cognitive and emotional response (Elliot and Maier, 2014). Though the use of colour is beneficial in infographic design, colours are frequently used ineffectively by information designers (Keyes, 1993; Madden et al., 2000; White, 2003; Conley, 2017). The misuse of colour can create greater difficultly for users and inhibit performance (Keyes, 1993). It is advised that colour should be used thoughtfully and with purpose, and applied to optimise communication rather than artistic appeal (White, 2003). It is suggested that colour should be limited to 2 or 3 colour hues, with variations in saturation and value suitable to create more distinction if needed (Stone, 2006). Murray et al. (2017) also suggest utilising between 3 and 5 complimentary colours in an infographic. This reduces visual clutter caused by using too many colours, especially the overuse of hue variation. The effect of colour on cognitive processing is also an important consideration for optimising information visualisation.

2.5.1. Colour in cognition and memory

As previously discussed, the more attention focused on a stimulus the greater the possibility it will be transferred to long-term storage (Sternberg, 2009; Pan, 2010). One effective method of attracting attention to information is the application of colour (e.g., Schaie and Heiss, 1964; Farley and Grant, 1976; Schindler, 1986; Wichmann et al., 2002). An eye tracking study by Jamet (2014) shows that the presence of colour attracted attention to the desired areas of information, thus, promoting learning. It has been shown that colour induces physiological arousal (visual sensory stimulation) which can increase visual memory (Wichmann et al., 2002; Spence et al., 2006). Kim (2010) also recorded that when comparing visual information with and without colour, participants using colour had significantly improved working memory for the information. Colour has also been found to significantly improve processing speed when effectively used on graph-based information visualisation (Klippel et al., 2009).

Furthermore, despite contradicting studies regarding colour and visual memory, there is some evidence that colour can positively influence longer-term memory (e.g. Wichmann et al., 2002). It has been found that object colour is stored in long term-memory (Hanna and Remington, 1996; Kuhbandner et al., 2015). Spence et al. (2006) also recorded a significant increase of visual memory for colour photographs, compared to black and white. The majority of available publications compare the presence or absence of colour (e.g., Farley and Grant, 1976; Wichmann et al., 2002; Spence et al., 2006). Selective use of colour to emphasise important information may yield better results. Alesandrini (1983) recognised the effectiveness of this technique in advertising to increase attention on information emphasised by colour. A study by Worley (1999) further investigated this technique by comparing diagrams of the heart using either highlighted colour, full colour or no colour. Only immediate recall was tested, and no significant differences found. The design of the diagrams could have also been improved as they used complex photograph-like images. Unfortunately, the potential effects of highlighted colour on long-term memory were also not considered.

A review by Dzulkifli and Mustafar (2013) on the influence of colour on memory concluded that colour is effective in increasing the chance of an environmental stimuli being “encoded, stored, and retrieved successfully” (Dzulkifli and Mustafar, 2013). As recognised by the authors, however, the review lacks evidence due to the limited research exploring the impact of colour for emphasis and long-term memory. Based on current memory models, the proven increase in attention from colour application would suggest a potentially positive impact on long-term information storage. The subject appears to be incompletely researched, particularly in the field of information and infographic design where it could yield beneficial findings. Despite this, the available research provides some support for colours positive impact on memory; colour can promote deeper information processing and increase relation to previous knowledge.

2.5.2. Colour coding

Colour coding is a prime example of the application of the signalling principle, mentioned previously, where essential information is emphasised (Mayer, 2009). Colour can be applied to signify connection of related information by displaying it in the same colour; in accordance with the Gestalt principle of similarity (Ali and Peebles, 2013). If colour coding in an infographic is consistent it can also be used to relate new information to prior knowledge, an effective method of learning (Mayer and Moreno, 2003).

Keller et al. (2006) also found colour coding enhanced knowledge acquisition, though the results were not significant. The authors acknowledge this may be due to their sub-optimal application of colour in the diagrams. More meaningful evidence can be observed from research by Scheiter and Eitel (2015) who investigated performance using 3 diagrams using: no signals, colour coded signalling and mismatched colour coded signalling (Figure 2.25). The results showed participants with colour coding signalling located quicker and more frequently observed the emphasised essential information, leading to significantly better performance.

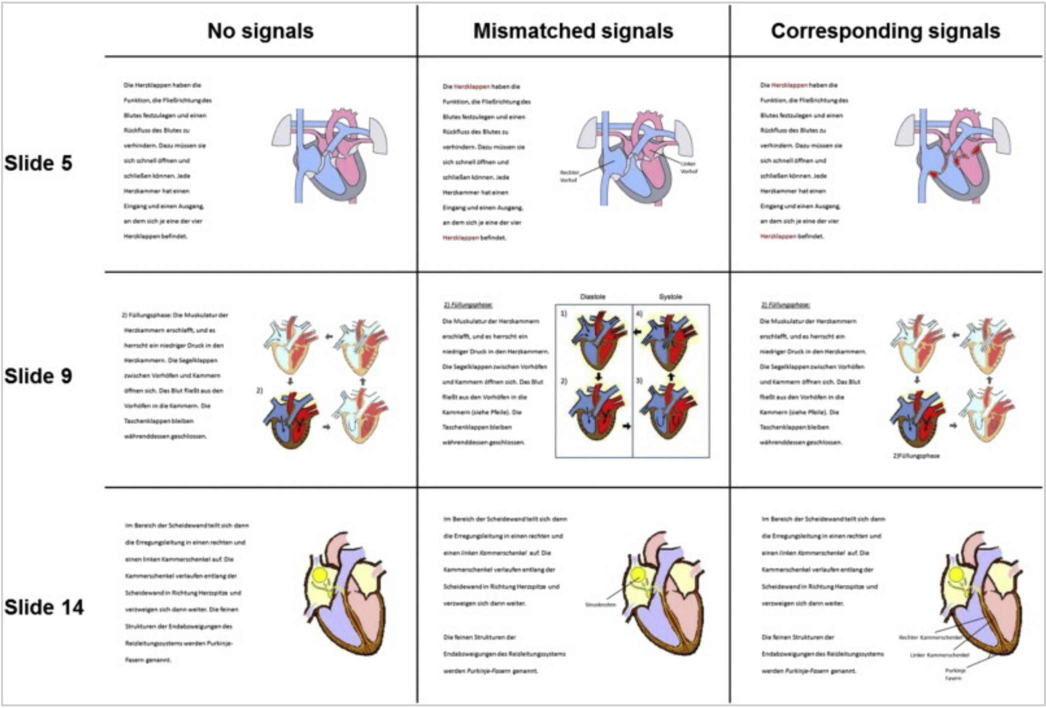


Figure 2.25 Shows the experimental designs testing by Scheiter and Eitel (2015) comparing colour coding, no coding and mismatched coding (Image from Scheiter and Eitel, 2015).

Further evidence from multiple eye-tracking studies show that colour coding is an effective means of optimising learning from visual information (e.g. Jamet, 2014; Ozcelik et al., 2009; Ozcelik et al., 2010). Ozcelik et al. (2009) showed that colour coding increased retention and transfer performance due to more efficient information location and increased attention. The findings were further confirmed by Ozcelik et al. (2010) who found that signalling guided attention and made relevant information location more efficient. The meta-analysis conducted by Richter et al. (2016), that reviewed 27 papers on signalling in multi-media learning, concluded that colour signalling was an effective means of enhancing learning; especially in those with low prior knowledge. Colour coding proves it to be an essential consideration in the design of infographics and should be used to emphasise essential information.

2.5.3. Colour Contrast

Research exists in the field of colour contrast using text print, finding greater brightness contrast leads to optimised readability (e.g. Preston et al., 1932; Hackman and Tinker, 1957; Tinker, 1959; Tinker, 1959). However, it cannot be assumed this applies directly to screen (Dillon, 1992; Dyson, 2004). The following studies consider colour contrast on web pages. Ling and Van Schaik (2002) observed the effect of differing colour combinations on a webpage navigation bar on the performance of visual search. The highest colour contrast between text and background performed best, which included blue text on white background, black on white and yellow on black. High colour contrast was found to result in faster searching as well as higher user preference. This finding is supported by Hall and Hanna (2004) who concluded the highest contrast of black and white had the highest readability scores. Further validation can be found by Moore et al. (2005), Mackiewicz (2009), and Galitz (2007) who stated information is recognised both faster and more accurately when background and text contrast is maximised.

The idea that maximised colour contrast using black and white text/background colour combination has been previously reported from print-based experiments (Holmes, 1931; Paterson and Tinker, 1931; Holmes, 1931). Such research has also found that black text on white is more legible than white on black, as has also been observed in more recent research on screen (Buchner and Baumgartner, 2007). Suggesting that when needing to maximise typographic legibility, most of the text should be black on a white background. This is not to say all text should be black on a white background, as colour application is frequently useful, but to carefully consider text and background colour contrast.

McConnohie (1999) and Hall and Hanna (2004) revealed the absence of colour in backgrounds increases visual memory. The increase in contrast by using a white background increases attention and memorability of a colour image or object in the foreground (Moore et al., 2005; Lloyd-Jones and Nakabayashi, 2009). Pettersson (2010) advises to consider colour legibility in information design by making colour differences clear and well-defined.

2.5.4. Colour meaning

Colour theory and the emotional response to specific colours is widely discussed in many design textbooks. However, this theory is frequently opinion or practice based so will not be used to define infographic colour design principle in this literature review. Instead, only research-based publications on colour meaning will be considered in this review. Adams and Osgood (1973) completed a cross-cultural analysis of colour meaning from 23 world cultures. Though response to colour can be individually dependant, some universal themes exist (Madden et al., 2000). They found red hues to be described as important and active. White, blue, and green were thought to be positive, with black and grey passive or negative colours. Yellow, white, and grey also being interpreted as weak, while red and black strong. Blue is the most preferred colour, also white is considered positively, and black negatively. Unfortunately, the all-male student participants may have had an influence on the results. However, the authors go on to reference multiple studies backing most of their findings.

Additional research has supported the theory that warmer colours attract more attention through increased arousal compared to cooler colours (Birren, 1978; Mehta and Zhu, 2009). Jacobs and Suess (1975) looked at the effect of 4 colours: red, yellow, green, and blue, on anxiety response in 40 participants; finding red and yellow inducing significantly higher states of anxiety than blue or green. Therefore concluding that cooler colours are more relaxing than more arousing warmer colours. Mehta and Zhu (2009) acknowledge the inconsistency in research findings regarding the effect of warm or cool colour on cognitive task performances. Their highly cited research found that red colour enhances performance on detail-orientated tasks where users recalled a significantly greater amount of information; explained by the increase in attention and detail focus due to the colour's common association with risk. The blue condition resulted in better performance on creative tasks, suggesting it was due to the colours effect on calming emotional response allowing users to think more freely.

Further research in context by Bonnardel et al. (2011) found blue, orange and grey to be the most preferred colours on webpage display; recording that indented list-based information recall being highest with the orange variant. Stating the presence of the warm colour orange may have increased user attention, though this effect was not explicitly proven. However, this is supported by Kuhbandner et al. (2015) who found users had significantly better memory of red and yellow colours over blue and green. Implications of this research, and those previously reviewed, for infographic design suggest using warm colours to emphasise important information and attract attention, and cooler colours if applied to larger bodies of text.

The effect of associative colour may also be an important consideration, where a colour is related to a common meaning (Elliot and Maier, 2014; Olurinola and Tayo, 2015). Research by Olurinola and Tayo (2015) showed that participants provided with words displayed in congruent colours demonstrated increased memory for the information over incongruent colours. This may be explained by linking information to prior knowledge, a known mechanism of enhancing long-term memory (Mayer and Moreno, 2003). For example, the colour red; because of its common association with danger it has been shown to increase user risk-aversion and vigilance (Friedman and Förster, 2002; Koch et al., 2008), and the colour blue with peace and openness (Mehta and Zhu, 2009). Designers are advised to understand the meaning of a colour in context and to take this into consideration (Vanka and Klein, 1995; Madden et al., 2000; Elliot Elliot and Maier, 2014; Conley, 2017). This not only provides further evidence for colours influence on memory, but also suggests designers should take into account colour meaning and association.

One other aspect of colour that should be taken into consideration is cultural and contextual meaning (Elliot and Maier, 2014; Conley, 2017). According to Madden et al. (2000), and Vanka and Klein (1995) the meaning of a colour, or combination or colours, can differ depending on culture. They advise the understanding of colour meaning in context and to take this into consideration when designing.

SUMMARY OF PRINCIPLES COLLECTED FROM THE LITERATURE REVIEW

Section 5. Colour design:

35. Colour preference

Avoid using colour based on personal preference, but instead to best communicate the information and support the purpose of the infographic (Conley, 2017).

36. Colour palette limitation

Limit your colour palette to 2 or 3 hues to reduce visual clutter, variations in chroma and value suitable if necessary (Stone, 2006).

37. Colour signalling

Utilise colour to attract attention and emphasise the most important information (Schaie and Heiss, 1964; Farley and Grant, 1976; Schindler, 1986; Wichmann et al., 2002; Jamet, 2014).

38. Colour memory

Apply colour to areas of information you want the user to remember (Wichmann et al., 2002; Spence et al., 2006; Kim, 2010; Dzulkifli and Mustafar, 2013).

39. Colour coding

Colour coding can be used to group information into chunks, that allow for easier comprehension and recall (Dwyer and Moore, 1991; Keller et al., 2006; Mayer, 2009; Ozcelik et al., 2009; Ozcelik et al., 2010; Jamet, 2014; Richter et al., 2016). Show related information is connected by using the same colour to display it (Worley, 1999; Mautone and Mayer, 2001; Mayer, 2009.

40. High background/text contrast

Make sure to use background and text colours with high contrast to maximise information legibility (Ling and Van Schaik, 2002; Moore et al., 2005; Galitz, 2007; Mackiewicz, 2009).

41. Black text, white background

Use black text on white background, over white on black, to increase legibility (Hall and Hanna, 2004; Buchner and Baumgartner, 2007).

42. Colour theory

Certain colours can have an effect on a user's emotional response to information, so take this into account when designing infographics. (Jacobs & Suess, 1975). For example, the cross-cultural belief that black and grey are negative while white, blue, and green are positive colours (Adams & Osgood, 1973; Madden et al., 2000).

43. Colour contrast legibility

Ensure applied colours obviously different to make differences in colour clear and well defined (Patterson et al., 2014).

44. Warm colours to highlight

Use warmer colours to highlight important information to increase attention, over that of cool colours (Birren, 1978; Mehta & Zhu, 2009; Kuhbandner et al., 2015).

45. Cool colours to relax users

Use cooler colours, such as blue, when wanting to relax users or for larger bodies of text (Bonnardel et al., 2011; Kuhbandner et al., 2015).

46. Associative colour

Consider common associations of a colour and utilise this, when appropriate, to link new information to prior information (Elliot & Maier, 2014; Olurinola & Tayo, 2015).

47. Careful use of red

Red is commonly associated with higher risk and can elicit increased levels of anxiety, use carefully to increase user vigilance for information in this colour (Friedman & Föster, 2002; Koch et al., 2008).

48. Colour in context

Avoid complex backgrounConsider what a colour may mean in content of the infographic information (Elliot & Maier, 2013; Conley, 2017), as well as the meaning of a colour, or combination of colours, to a culture (Vanka & Klein, 1995; Madden et al., 2000).

49. Complex backgrounds

Avoid distracting backgrounds such as gradients (Lonsdale & Lonsdale, 2019).

2.6. Layout design

One vital consideration in the design of infographics is the layout. The layout provides the base structure of the design and is fundamental in conveying the displayed information. It can be utilised to create hierarchy and can dictate the order in which a user processes information, through multiple interacting variables, and should be carefully manipulated to optimise the understanding of the infographic. Effective means of creating hierarchy include variations in: colour, typography and physical layout (e.g. Puhalla, 2008; Lonsdale, 2014; Arslan and Toy, 2015). Although research within the niche field of infographic structuring and hierarchy is limited, there exists some useful publications exploring the upcoming field.

2.6.1. Layout design background

To understand some of the research in colour organisation, first, a background on the three properties that constitute a colour should be described. The first property that defines a colour is known as 'hue'. This is the basic pigment of a colour (Mackiewicz, 2009) and the way in which the human eye perceives the particular wavelength of light (Kimball and Hawkins, 2008). Simply put, when someone describes a colour as red, yellow or blue; they are describing the colour's hue (Conley, 2017). The second property is known as value and describes the lightness or darkness of a colour (Conley, 2017). It is the amount of light displayed in a colour. A 'tint' or 'shade' of a colour hue is actually referring to the value of a colour; where a "tint" is the addition of white and "shades" the addition of black (Learn., 2019). Finally, the third property is saturation (or chroma) and refers to the intensity of a colour, or the relative amount of hue displayed (Mackiewicz, 2009). It can be considered the amount of both black and white added to a colour; the more grey is added the lesser a colours hue intensity is exhibited (Learn., 2019). See the Figure 2.26 for an example.

Figure 2.26 Displays the different properties that make up a colour, including: hue, saturation, and value (Medium, 2015).

Conley (2017) acknowledges that colour can be applied by designers to facilitate in user understanding of visual hierarchy and the order of information. However, the author also concludes that colour structuring has a weak theoretical basis because of the lack of research in the field of colour organisation. Despite this, a select few research papers explore the potential implications of colour dominance that will be reviewed next.

2.6.2. Colour hierarchy

Puhalla (2008) investigated the perception of dominance based on variation in a colour's hue, value, and saturation, and how this can reinforce information hierarchy. It was hypothesised that variations in colour would result in differing user defined hierarchy; though the infinite colour variations available makes it difficult to define specific results. The colour yellow has the highest value, followed by orange, red, green, blue, and purple. The research itself was focused around these 6 colour hues, these were used to create 18 colour combinations comprised of 3 colours with variation in hue, value, and saturation. Typeface was used as a way to display the colour in the form of a title, to apply the experiment in the context of information hierarchy. A total of 99 university students participated in the study and were asked to select the most dominant colour of the 3 displayed in each 18 variations - see Figure 2.27. A significant majority of users selected the most highly saturated colour as being the most important or dominant. Value was not as decisive but generally users selected the darkest contrasting colour. Variations in hue was indeterminate with inconclusive results. Out of the 18, the only variation that participants had clear difficulty selecting a dominant colour was the one where only the hue changed between the 3 colours. Suggesting hue variation alone is not enough to define a colour of dominance. The author expresses the importance of colour contrast stating it plays a significant role in the selection of a dominant colour. Overall, the results suggest that the use of a highly saturated, and perhaps darker, colour promotes the highest interpretation of colour hierarchy. In context of infographic design this research recommends using highly saturated colour to emphasise the most important information, taking into account that it should also be highly contrasting to achieve this. This study is the only well-constructed publication found regarding colour dominance in information design.

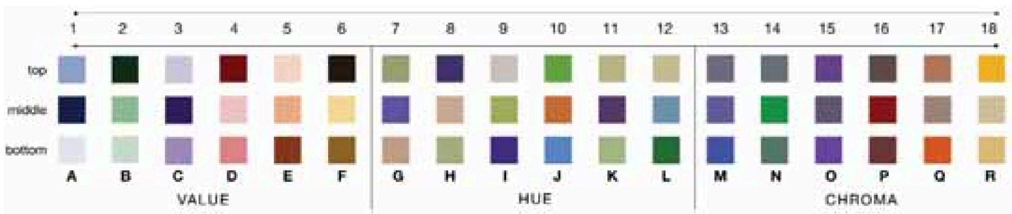


Figure 2.27 Displays the colours that were tested by Puhalla (2008) in their study examining colour dominance – image from Puhalla, 2008.

As previously mentioned, evidence also exists describing the colour red as dominant and attention demanding to the human eye (e.g. Jacobs and Suess, 1975; Mehta and Zhu, 2009). Often associated with danger and inducing higher levels of anxiety, it is suggested that the colour red should be used carefully. Similarly, warm colours have been found to be more arousing and attract greater attention than cooler colours (Birren, 1978; Green et al. 1983 Greene et al., 1983; Mehta & Zhu, 2009). Consideration of the research therefore advises a designer to consider utilising warmer colours for information of greater priority, or of desired higher hierarchical rank. However, as suggested by Puhalla (2008), hue may not be the best means to communicate hierarchy; though it is still worth taking into consideration given the supporting research.

2.6.3. Typography and headings

Typographic design is a more obvious and better researched method of creating visual hierarchy. However, as pointed out by Arslan and Toy (2015), it is frequently poorly applied in infographic design with not enough visual hierarchy to distinguish headings, titles and text. As recognised in the review by Lonsdale (2014), using bold text is a successful method of emphasising the importance of information. Lonsdale (2014) advises appropriate contrast between type weights when using bold to ensure it appears purposeful and obvious. It is also recommended that, because of bold's attention attracting nature, it should be reserved for specific words or headings; rather than entire sentences (Lonsdale, 2014).

Similar results have also been observed on computer screen-based mediums. A comprehensive research study by Pelli et al. (2006) on letter identification found that bold letters were more efficiently recognised than regular letters. Macaya and Perea (2014) explored this finding in textual context and found that bold typeface facilitated word recognition in both serif and sans-serif typeface. Finding that within a sentence, a bold word was recognised significantly faster than a word of regular weight when displayed on a computer screen.

Another successful method of hierarchy establishment using typeface is by manipulating the size of the type. Larger type, in relation to the rest of the text size, appears more important. Evidence for this is found in research by Williams and Spyridakis (1992), who observed that the size of text was the most powerful visual cue to signify a headings hierarchal placement; over position, underlining and letter case. The greater the relative difference in size between headings and bodies of text, the faster they were identified; suggesting headings should be noticeably larger than the information body. The authors suggest headings that are 20% larger than the text, are most beneficial to the user. Another important finding from the publication is that headings are easier to identify when they vary on fewer typographic or formatting dimensions. A title defined by a single dimension, such as size, was identified faster than those defined by a combination of parameters (e.g., size, uppercase and underlined). Meaning that headings should be defined by limited variables, such as only type size and weight, rather than as many parameters as possible.

The importance of headings has been previously noted by researchers; when headings are present users find information easier to find during a visual search task (e.g. Kools et al., 2008). It has also been observed that users recall significantly more information from when headings are present (Dee-Lucas and Di Vesta, 1980; Hartley and Trueman, 1983; Krug et al., 1989). Hyönä and Lorch (2004) state that headings signify the beginning of a new topic and encourages the opening of a new memory slot, as supported by their eye-tracking data.

Unfortunately, the positive impact of headings in online or multimedia information has been ineffectively researched. However, Jin (2013) investigated the effect of implicating visual guidelines to create hierarchy in digital text; design guidelines were beneficial in improving digital text comprehension. Despite the lack of digital-based publications, the research suggests the presence of headings in infographic design is important in establishing visual hierarchy and information location, with a larger type size being the best way to define a title.

2.6.4. Layout structure

One of the most important methods of designing visual hierarchy is through the physical placement of the elements that make an infographic; these include: graphics, text and colour. Arslan and Toy (2015) highlight that layout is often poor quality in current infographics, and that a clear, structured and hierarchical layout should be prioritised. Murray et al. (2017) also emphasise the need to create an understandable narrative when designing infographics. This can be achieved through the inclusion of elements encourage desired reading path (e.g., arrows/lines).

Although research focusing specifically on infographics is limited, a recent publication by Majooni et al. (2018) effectively addressed the effect of infographic structure and its impact of cognition and information comprehension. The eye-tracking study was undertaken by 20 participants that compared multiple viable infographic layouts, these being: stairs (A1), zig zag (A2), vertical columns (B1) and horizontal columns (B2) – see Figure 2.28. An overall score was calculated taking into account a comprehension questionnaire score and the eye-tracking data. These were as follows: A1 = 76%, A2 = 96%, B1 = 60%, B2 = 51%. Based on the data the zig zag structure performed the best, as this follows the natural reading pattern of the English language in a left-to-right and up-to-down pattern. Infographic layouts should take natural reading patterns into account to maximise legibility.

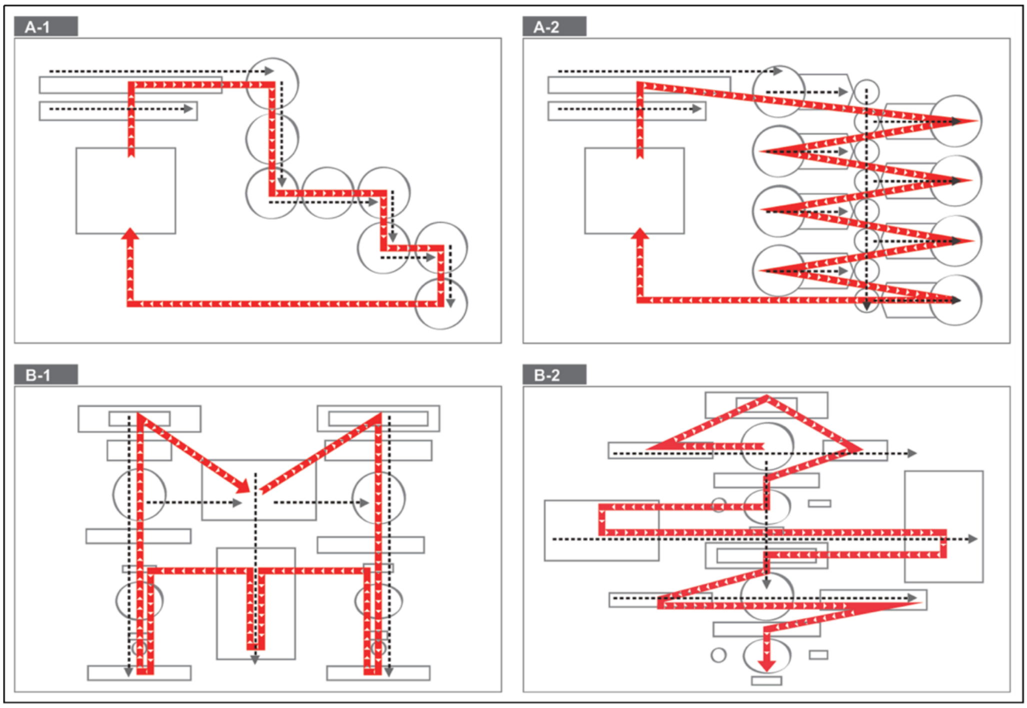


Figure 2.28 The 4 infographic layouts that were tested by Majooni et al. (2018).

Stones and Gent (2015a) published a series of guidelines for creating infographics to display public health information, informed by their own previous research experience and an eye-tracking study with 42 participants investigating how users interpret 3 different infographic layouts. They advise aligning the elements of an infographic in a grid to make it more organised, as eye movements were very predictable when using a left-to-right grid layout. Eye movement was much less predictable in less structured infographics designed without a grid. Zhang (2017) conducted a study exploring users' opinions on infographics through a focus group. It is recommended that designers should create infographics with a coherent design style. Consistency should be achieved by standardising certain elements such as typography and colour palettes when representing a specific brand or organisation (Zhang, 2017).

Although research is currently relatively limited in infographic structure and hierarchy, recent publications over the past few years have made important findings to establish the foundation of this field. Through the consideration of colour, typography and layout variables a designer can create infographics with a purposeful sequence. This can not only optimise the appearance of an infographic, but also assist in the understanding of the information.

SUMMARY OF PRINCIPLES COLLECTED FROM THE LITERATURE REVIEW

Section 6. Layout design:

50. Colour dominance
Use a highly saturated colour for information of greatest importance, this has greater ratings of importance than variations in hue of colour value (Puhalla, 2008). Highly saturated (darker) colour is most dominant (Puhalla, 2008).

51. Colour palette contrast
Ensure contrast is high when colour is applied on infographics (e.g., between background and colour, or between colours). This makes dominance clearer (Puhalla, 2008).

52. Warm colour dominance
Warm colours have dominance over cooler colours, where warm colours attract greater attention (Jacobs & Suess, 1975; Mehta & Zhu, 2009).

53. Bold attracts attention

Use varying type weight to attract attention and create dominance, where bold text attracts more attention than regular text (Pelli et al., 2006; Lonsdale, 2014; Macaya & Perea, 2014).

54. Type weight contrast

Ensure that contrast in weight is noticeable between a regular and bold text (Lonsdale, 2014).

55. Bold text limitation

Due to the attention-grabbing nature of bold text reserve it for specific words and headings, instead of entire sentences (Lonsdale, 2014).

56. Dominant headings

Use headings to effectively organise information and make information easier to find, they should be one of the most dominant elements of the infographic (Hyönä & Lorch, 2004; Kools et al., 2008; Jin, 2013).

57. Define headings

Use variation in type weight to establish a heading or title, with larger text being interpreted as having greater dominance (Williams and Spyridakis, 1992; Lonsdale, 2014).

58. Make headings larger

Text size is the most powerful cue to signify headings hierarchical position. Ensure a heading is roughly 20% larger than the body of text, to ensure the size difference is obvious (Williams and Spyridakis, 1992).

59. Heading parameter limit

Define headings by a limited number of parameters (e.g., size and weight), as they are recognised slower when defined by too many (Williams and Spyridakis, 1992).

60. Layout narrative

Layout of infographics should be clear and structured to create an understandable narrative with an obvious order to the information (Murray et al., 2017).

61. Zig-zag structure

Display infographic information in a zig-zag structure to mimic the natural reading pattern of the English language and optimise comprehension (Majooni et al., 2018).

62. Reading pattern

Make sure information is displayed in a left-to-right, top-to-bottom order structure to mimic the natural reading pattern of the English language and optimise comprehension (Majooni et al., 2018).

63. Layout grids

Present the infographics in a clear grid-based format as this makes eye movements more predictable and allows a designer to control the order of information consumption (Stones & Gent, 2015; Majooni et al., 2018).

64. Branding consistency

Create consistency between infographics with coherent design elements if representing single organisation or brand (Zhang, 2017).

2.7. Image and graph design

As one of the two elements that create an infographic, along with typography, graphics are a core consideration in their design. Unfortunately, there is a lack of specific research in infographic imagery, so other related fields are consulted including health information visualisation, which has a greater breadth of research. The benefit of visualising complex health information has been effectively recognised; experimental research has shown the inclusion of graphics to illustrate text assists in information comprehension (Choi, 2011;

Tae et al., 2012). A research review by Houts et al. (2006) considered the impact of "pictures" in improving recall, adherence, comprehension and attention of health information. They concluded that graphics which assist in the communication of complex health information but should be simple in their design.

2.7.1. Infographic imagery

As has been previously stated decorative illustration, known as "chart junk", should be removed as this provides no benefit to the comprehension of information and instead can act as a distraction from the essential information (Mayer, 2009; Patterson et al., 2014; Lonsdale and Lonsdale, 2019). Instead, illustration should exist in an infographic to serve the purpose of visualising and simplifying the written information (Dunlap and Lowenthal, 2016). Dunlap and Lowenthal (2016) found that effective infographics use relevant images, with less effective design including decorative and distracting imagery; concluding that graphics should be clear, related, and simple. Embellishment should be limited and then only applied to provide context to information, not to distract from it (Lonsdale and Lonsdale, 2019).

Arslan and Toy (2015) emphasise the common mistake of using non-original graphics created by other designers in infographics, creating potentially distracting and disintegrated elements. Instead, recommending that infographic images should be originally designed to create a cohesive infographic tailored towards the designs content.

Another important graphical consideration in an infographic involves the intended reading order of an infographic. Murray et al. (2017) state that effective infographics have a clear narrative where the intended order of information is clear. One successful way doing so is through the graphic inclusion of lines and arrows that clearly lead a viewer's eye from one section of information to the next; as related to the Gestalt principles of connectedness and continuity (Graham, 2008; Ali and Peebles, 2013; Gkogka, 2018).

2.7.2. Graphic illustration

Stones and Gent, 2015a published a series of guidelines on visualising public health information. In respect to graphics, it is again recommended that imagery should enhance not distract from data. They categorise illustration into 10 types, stating that an infographic should limit how many types are used to avoid overwhelming the reader. Simplified graphics are also said to result in the most efficient comprehension (Zikmund-Fisher et al., 2008; cited in Stones & Gent, 2015; Mollerup, 2015), recommending pictograms over cartoons if a more objective tone is required, as is often necessary in infographic design.

There is, unfortunately, limited available research comparing the effectiveness of different types of graphics (e.g., complex illustration, photograph, pictogram). However, there is a large body of healthcare publications emphasising the effectiveness of pictograms; this simple illustration format appears to be most beneficial. The presence of pictograms has been proven to benefit the procurement and comprehension of complex healthcare information (e.g. Dowse and Ehlers, 2005; Choi, 2011; Dowse et al., 2011), especially in those with lower literacy skills (Mansoor and Dowse, 2003; Kripalani et al., 2007; Park and Zuniga, 2016). Where graphic simplification seems to be key in optimising user understanding complex information, pictograms appear to be an appropriate choice of illustration to accompany infographic text.

It is recommended that pictograms not be too detailed but easily distinguishable (Tijus et al., 2007), and be accompanied by an explanatory caption to ensure their intended interpretation (Choi, 2011; McCready, 2016). Van Beusekom et al. (2017) state that pictograms should be simple, finding users of lower literacy skills had difficulty understanding more complex graphics. McCready (2016) publishes a series of practise informed guidelines for the design of infographic icons. These include: limiting colour application; use a consistent design style; use background shapes to emphasise icons; and ensure size is proportional and consistent.

Research suggests pictograms, over complex illustration, are an appropriate option in infographic design to optimise legibility. However, the effectiveness of a pictogram should be based on if the user can understand it (Tijus et al., 2007), suggesting a designer should carefully consider the information it is representing. This style of illustration may not always be appropriate to the content, however, but the designed graphics should still be simple and cohesive to the infographic content.

2.7.3. Graphs

Inconsistent results have been observed regarding the application of "chart junk" when designing graphs. Bateman et al. (2010) published a study investigating the effect of graph embellishment on comprehension and memorability of information. They acknowledge the existing guidelines recommend using simple graphs and to remove the any unnecessary visual embellishment. They suggest that complex stylised graphs could be more memorable or help to convey their message. Bateman et al. (2010) compared embellished and plain charts that displayed the same information an found no difference in comprehension. Though, they did observe significantly better long-term memorability for the embellished chart information. The results of the study, however, lacks statistic confidence given the small sample size of 10 participants per group.

Supporting evidence was recorded by Li and Moacdieh (2014) who compared embellished and simple graphs with a high number of data points. They found no significant difference in comprehension on long-term recall between the embellished and simple charts but found significantly better short-term recall using the embellished graphs. Opinion data was also mixed with participants finding information faster with the plain graphs but finding the embellished graphs easier to visualise. The participants also reported finding the embellished charts distracting, too cluttered and busy, and unprofessional. The eye-tracking data from the study also showed the participants spent more time focusing of the data when using the plain charts. Again, statistic confidence in the results of the study is poor given the 10 participants used for the study. Despite the inconclusive results of the study the authors conclude by recommending embellished graphs. It can be argued that the simple graphs that were tested in both studies were poorly designed. The simple graphs lacked any colour application which may explain the decreased memorability of the information observed in the studies; a disparity not considered by the authors.

Contradictory results has been recorded by Skau et al. (2015) who recruited 100 participants to compare simple and stylised bar charts. They found that the majority of the embellished charts performed significantly worse, as measured by accuracy of comprehension. Concluding that embellishing primary chart elements reduced communication accuracy. Though there may be some weak evidence for using embellished charts to increase memorability, the evidence from Skau et al. (2015) and well as recommendations from multimedia design (e.g. Mayer and Moreno, 2003) and Gestalt theory lead this literature review to recommend the use of simplified graphs. However, this does not mean graphs should be basic and unengaging. Instead, colour should be used to emphasise important data (Wichmann et al., 2002; Jamet, 2014) and create attractive visualisation.

Zikmund-Fisher et al. (2008) also found simplifying graphs improved their comprehension. In their study pictographs were better understood than a more complex 4 option multi-layer bar graph of the same data, recommending the use of easy-to-understand graph formats. Complex pictorial backgrounds have also been found to reduce performance accuracy (Gillan and Richman, 1994). Another consideration for infographic designers is to avoid the temptation to display too much information in a single graph, an understandable error when information is being condensed, and instead use multiple graphs if more appropriate (Gelman and Unwin, 2013). Again, research suggests, even in the context of graphs, that the visualisation should be simple when user comprehension is key.

A review by (Hildon et al., 2012) investigated differing graph formats, bar charts were preferred but pictographs were understood the easiest. Support for pictograph (or unit chart) format has also been previously observed when visualising healthcare information, especially in lower-literacy participants (Hawley et al., 2008). When designing pictographs there should be strong contrast in colours between the different variables to optimise comprehension (Stones and Gent, 2015a).

In terms of bar charts, Stones and Gent (2015a) suggest keeping them simple and to avoid adding embellishment to already complex data visualisation. Users also perform worse with stacked bar charts, compared to non-stacked, so they should be avoided (Cleveland & McGill, 1984). When compared to 5 other forms of graph (including bar and pictograph), pie charts were found to perform the worst (Hawley et al., 2008). Though lacking in accuracy, pie charts can still be useful to display basic percentages where exact figures are not essential (Spence, 2005). When a pie chart is utilised, it is recommended that they are clearly labelled as the actually data value is hard to discern from the visualised area (Stones and Gent, 2015a). All 3 forms of graph are effective methods of conveying graphical data, if used correctly.

SUMMARY OF PRINCIPLES COLLECTED FROM THE LITERATURE REVIEW

Section 7. Graphic design:

65. Content consideration
Visual elements should be consistent with the function, content and key message of the infographic, and determined early on in the design process (Lonsdale & Lonsdale, 2019).

66. Simple graphics
Use strong, single graphic and graphs over complex ones to maximise user comprehension of the imagery (Houts et al., 2006; Zikmund-Fisher et al., 2008; cited in Stones & Gent, 2015; Mollerup, 2015).

67. Remove "chart junk"
Infographic illustration should exist with purpose, to explain and aid in the comprehension of written information (Dunlap & Lowenthal, 2016). Visual embellishment should be removed to avoid unnecessary distraction, it should only be used to provide context to information (Zikmund-Fisher et al., 2008; Mayer, 2009; Gelman and Unwin, 2013; Patterson et al., 2014; Skau et al., 2015; Dunlap & Lowenthal, 2016; Lonsdale & Lonsdale, 2019).

68. Original graphics
Create original illustration, instead of applying other designer's images, to avoid unconnected or distracting imagery (Arslan & Toy, 2015).

69. Graphic order

Use elements, such as lines and arrows, to create a clear narrative order (Graham, 2008; Ali & Pebbles, 2013; Murray et al., 2017; Gkogka, 2018).

70. Style variation limitation

Limit the types of graphic utilised to prevent overwhelming the user (Stones & Gent, 2015).

71. Pictograms increase comprehension

Use pictograms (over cartoons or basic shapes) if an objective tone is required (Stones & Gent, 2015), or to increase accessibility and comprehension in lower-literacy level users is key (Mansoor & Dowse, 2003; Dowse & Elhers, 2005; Kripalani et al. 2007; Park et al., 2016).

72. Icon backgrounds

A background can be applied to an icon to emphasise it (McCready, 2016).

73. Graphic consistency

Ensure there is a consistent style across the graphics of an infographic (McCready, 2016).

74. Proportional icons

Ensure icon sizes are proportional to create visual balance (McCready, 2016).

75. Representative graphics

Ensure that graphics are clearly representative of the information they are visualising (Tijus et al., 2007).

76. Graphic captions

Ensure graphic (pictograms) are accompanied by an explanatory caption to ensure intended interpretation (Choi, 2011).

PRINCIPLES SPECIFIC TO GRAPHS

77. Avoid graph backgrounds

Avoid complex pictorial backgrounds on graphs as they can reduce performance accuracy (Gillan & Richman, 1994).

78. Graph over-information avoidance

Avoid trying to include too much information in a single graph, where multiple graphs may be more appropriate and easier to understand (Gelman & Unwin, 2013).

79. Pictographs

Pictographs are useful for displaying data to users with lower literacy abilities, they are easiest to understand (Hildon et al., 2012).

80. High graph colour contrast

Make sure colour contrast between variables is strong, with the important statistic emphasised (Stones & Gent, 2015).

81. Bar charts

Use simple bar charts to clearly display information (Stones & Gent, 2015).

82. Avoid stacked bars

Performance is worse when using a stacked bar charts, so avoid their use (Cleveland & McGill, 1984).

83. Pie charts for percentages

Pie charts are useful to display simple percentage data, but avoid for more complex data where accuracy is required (Spence, 2005; Hawley et al., 2008).

84. Pie chart labelling

Clear labelling of data values is important in a pie chart because it is hard to discern accurate data values from estimated area (Stones & Gent, 2015).

2.8. Case study – NHS sepsis screening poster

The 84 infographic design principles were applied to a preliminary case study. The principles were used to evaluate an infographic that was designed by an NHS doctor. The infographic was to be displayed in a hospital and directed at staff members to promote a new sepsis screening tool. The original infographic was assessed using the 84 principles, many were not applied in the first design. These are listed below and were applied in the redesign process of the infographic:

Cognitive principles

1. Signal important information
6. Attract exogenous attention
7. Attract endogenous attention
10. Create hierarchy
13. Align information

Gestalt principles

14. Proximity
21. Focal point
22. Connectedness

Typographic principles

27. Avoid capitalised letters
30. 9-12 pt Type size
32. Left text justification
33. 1.5-2 line spacing
34. Clear text style

Colour principles

37. Colour signalling
38. Colour memory
39. Colour coding
44. Warm colours to highlight
45. Cool colours to relax users
46. Consider associative colour
47. Careful use of red

Layout principles

50. Consider colour dominance
53. Bold attracts attention
56. Dominant headings
58. Make headings larger
60. Create layout narrative
63. Layout grids

66. Simple graphics
68. Original graphics
71. Pictograms increase comprehension
72. Icon backgrounds
75. Representative graphics

The infographic before and after being redesigned can be viewed at Figure 2.29 below. Although no research was undertaken at this stage to investigate the potential improvement between the two designs, it appears that that the infographic designed to apply the design principles more clearly communicates the information; though this statement is not evidence based. The redesigned poster was displayed in NHS Leeds Teaching Hospitals to display audit findings, and resulted in an uptake of the new sepsis screening tool. Raw research results were unavailable to the researcher as the audit was completed confidentially by the NHS. More detailed experimental research takes place later in the project on this subject, but the resulting redesign from this case study suggested that the application of principles may improve the infographic.

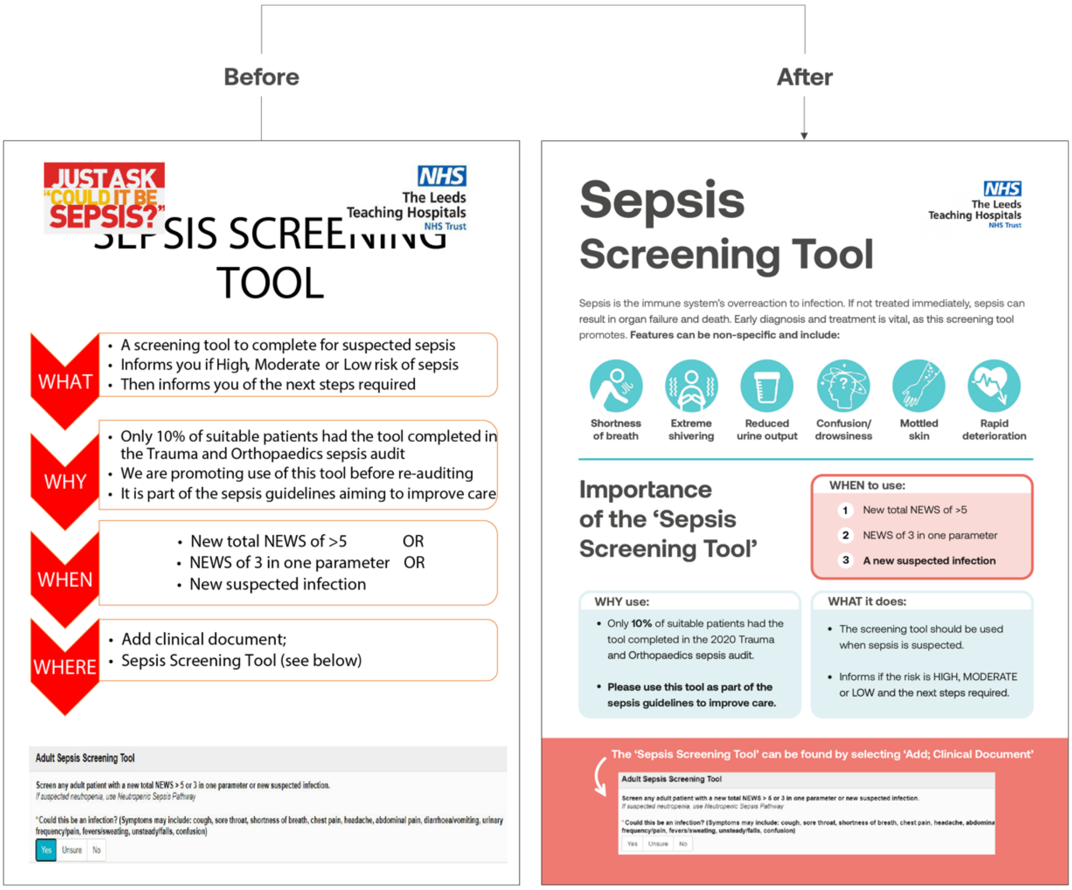


Figure 2.29. An infographic poster displaying NHS sepsis screening information, before and after the application of design principles defined in this review.

2.9. Literature review summary

Currently, infographic specific research is limited, and few publications have directly addressed design features that could impact infographic design. Despite this, many fields applicable to infographic design have explored design guidelines that can be utilised to improve the design of an infographic. This 'improvement' is defined in many forms, though typically it involves the optimisation of: accuracy of comprehension, speed of information location, information memorability, aesthetic ratings, or user preference. For example, this can be achieved by improving reading speed through appropriate text size, or by optimising the identification time of important information using colour application. This literature review evaluated this research, defining a set of 84 infographic design principles from relevant fields including: cognitive processing, Gestalt theory, layout, colour, typographic and graphic design.

It was hypothesised that the application of these principles would result in an 'improved' infographic. This was explored in Chapter 3 where the practical application of these principles is investigated. Chapter 3 looked to test this hypothesis by designing infographics that apply the 84 infographic principles in varying degrees of success, and examining if infographics can be improved by adhering to these principles. 'Improvement' was measured at this stage by accuracy and speed of comprehension, information location, information memorability, aesthetic ratings, or user preference. This was to reflect the parameters that were typically used by the publications included in this literature review. The design principles described in the literature review are summarised in Appendix 1.

3. Chapter 3 - Testing infographic design principles

3.1 Chapter 3 introduction

The literature review completed in the previous chapter defined 84 infographic design principles. This chapter tests these principles and investigates if their application results in an observable improvement in the effectiveness of infographic design. In this project the 'effectiveness' of an infographic is measured by information location speed and accuracy, information memorability, aesthetic rating, and user opinion. Given that the project used public health as a case study, the infographics tested and developed all contained public health information.

The chapter is divided into 3 stages:

- **Stage 1** – Infographic perception questionnaire
- **Stage 2** – Infographic design development
- **Stage 3** – Infographic comparative study

The first stage of the chapter was an initial investigation into user perception based on the application of the 84 design principles defined in the previous literature review. A questionnaire was completed using public health infographics that had been categorised as 'good', 'average' and 'poor' based on the application of the principles. The main aim was to understand if the categorisation of infographics into these categories was reflective of how they were interpreted. As well as investigating differences in infographic interpretation between designers and the public. The results found a positive correlation between the use of infographic principles and higher user opinion ratings. This was used as justification for further experimental research to compare participant performance when using infographics of varied design principle application.

The second stage centred around infographic design to developed the resources that would be used in the next comparative testing stage. These infographics were developed in 3 distinct categories; 'good' (84/84 principles applied), 'average (42/84 principles applied) and 'poor' (1/84 principles applied). The design of the infographics were based both on the application of principles as well as an analysis of online infographics to investigate common design features, in order to create representative designs. Original design took place at this stage to create bespoke infographics to fit the defined categories.

The third stage was an in-depth investigation into the effectiveness of the 3 infographics that had been developed in the previous stage. Stage 1 indicated that utilising design principles resulted in high opinion ratings. This stage aimed to collect more conclusive evidence that principle adherence could improve public health infographic design. The overall aim of the third stage was to find statistically supported evidence that the effective application of design principles can improve the design infographics. Though the answer may appear obvious, there is minimal research in the field of design that explores how design principle utilisation can positively impact user performance measures, especially concerning infographics. The use of design principles to optimise infographics cannot be considered fact without researched based proof, a common concern in the field of design where practise-based opinion is frequently described as fact. Positive results can provide important evidence that design principles are an essential consideration in the design of visual information. This stage was also used to investigate if a high level of principle application was required to maximise effectiveness. Significant improvements in effectiveness for the 'good' design, compared to the 'average' and 'poor' would suggest a high level of principle application was necessary to optimise public health infographic outputs.

A comprehensive study was completed that collected quantitative data in the form of information location time and accuracy, short-term and long-term information memorability. Supporting quantitative opinion data was also collected, and eye-tracking software to examine user viewing patterns in the infographics. The findings found supporting evidence, suggesting the application of principles effectively improves the design of public health infographics. Additionally, a high level of principle application (e.g. the 'good' design) was required to optimise design effectiveness.

3.2. Initial principle testing

3.2.1 - Public health infographic analysis

Initially, the design principles were preliminarily tested to establish if the application of design principles resulted in better user opinion ratings. A secondary aim was also to investigate if the categorisation of infographics, based on design principle application, was also reflective of their perception. This was completed using an online questionnaire with public health infographics that were collected online. Questionnaires are an effective research method for collecting the opinion of large groups of people, generating data that can be quickly analysed in order to explore common trends (Rowley, 2014). Another reason for the utilisation of an online questionnaire was that this method can be easily distributed and completely remotely.

A collection of 55 infographics were collected. These were categorised into 'good', 'average' or 'poor' based on their application of the infographic principles. Currently, there are no established thresholds for acceptable design principle implementation. To inform the definition of these thresholds for this thesis, established public symbol comprehension standards were consulted. Currently there are two existing standards for comprehension acceptability in public symbols; these being from the International Standards Organisation (ISO), and the American National Standard Institute (ANSI) (An and Chan, 2017). The ISO standard for symbol comprehension is 67%, meaning visual symbols have to be correctly interpreted at this percentage or above to be of acceptable standard. However, the ANSI threshold values state that comprehension should be above 85%. Adapting these visual symbol comprehension thresholds allows for the implementation of recognised design acceptability tolerances to help ensure a level of validity to the categorisation process.

When interpreting these values in the context of infographic principle application, a valid rate of acceptable design threshold would appear to be above a value in the range of these two percentages (67-85%). So, in this context, 80% was selected as the threshold value for a 'good' infographic. In other words, to be categorised as a 'good' infographic they had to apply at least 80% of the 84 design principles defined in the literature review. For the 'poor' category, this was reversed; with a 20% or below application rate used as the threshold value to be categorised as 'poor'. Equally, the 'average' category also used a range of 20%, selecting a 40-60% principle application number to be defined to this category. If any infographics fell into the 21-39% and 61-79% application area, they were discarded for not fitting within any category. This buffer area was purposeful between each of the threshold boundaries, as it reduced the effect of dramatic differences in categorisation due to small percentage variations. By removing designs that fit this buffer area, it ensured that there were clear distinctions in the number of principles applied in the designs within each category.

This process resulted in the removal of 25 infographics that did not fit into the defined ranges; leaving 30 infographic, 10 per category. It is understood that this categorisation has a degree of subjectivity, as the application of a principle was determined by the opinion of the researcher. However, the one of the purposes of the questionnaire was to determine if this categorisation was reflective of how the infographics were perceived. A positive correlation between categorisation and user perception was hypothesised. Evidence supporting the accurate categorisation infographics into 'good', 'average', and 'poor' was necessary for the later experimental research, that compared performance with infographics designed to represent these categories.

A pilot was employed using these infographics to assess the questionnaire design, as recommended by Farrell (2016). Feedback indicated that the questionnaire was too long. In response to this, the questionnaire was reduced to 15 infographics (5 per category), and the qualitative data collection reduced to an overall section at the end of the survey. It is recommended that online questionnaires should be short, to maximise the potential response rate (Nielsen, 2004). The 5 highest and 5 lowest scoring infographics were retained, as well as the 5 infographics scoring closest to 50% for the 'average' category. Consequently, the newly designed questionnaire was much faster and took roughly 15 minutes to complete.

An aim of the questionnaire was to establish if the application of infographic principles correlated with user judgement. The purpose of this was to collect rapid preliminary results investigating the potential effectiveness of applying infographic principles, to determine if they warranted further experimental testing. It was hypothesised that infographics that applied more design principles would be more positively received by users. If this were confirmed, it would provide some evidence that the application of design principles results in better interpreted infographics. It would also find support for the categorisation of infographic quality based on their design principle application.

A second aim of the questionnaire was to explore if designers and the general public interpret infographic design in similar ways. The questionnaire took place using 70 participants; 35 participants from the general public and 35 designers. The designers were either working or studying in the field of information design; so had experience with design theory and principle application. If designers and the public interpreted the designs in very similar patterns, it would suggest that an understanding of design theory was not required to recognise high quality infographics, and that principle application may be reflective of infographic quality interpretation.

3.2.2 Methodology

The questionnaire itself consisted of 15 sections, each displaying an infographic. Participants were asked to consider the design of the infographic, and to rate them based on their design qualities. Participants were asked to disregard the content of the infographic. The participants rated the infographics as 'poor', 'satisfactory' or 'good' based on 5 categories. These categories were as follows:

1. Overall design and appearance
2. Colour combination
3. Text legibility and readability
4. Layout and organisation of information
5. Graphics (illustrations, icons, lines, arrows, etc.)

The final section of the questionnaire asked the participants to describe the main design problems with the infographics they rated as 'poor', as well as the main design qualities with the infographics they rated 'good'. This was to gather qualitative data to better understand common features of the infographics that were considered effective or ineffective.

3.2.3. Results summary

The categorisation appeared to be reflective of how the infographics were interpreted by both designers and the general public. Generally, the 'good' infographics were positively received, the 'average' infographics incited mixed opinions, and the 'poor' infographics were negatively received. When looking at specific infographics there was 3 most favoured and three least favoured designs from the 15 infographics, this being the same for both the designers and general public. The three most favoured designs were: 02. Heart Health, 03. Lung Cancer, 04. Malaria; all from the 'good' category. These were also the 3 infographics that applied the most infographic principles. The three least favoured were: 12. Alzheimer's, 14. Dengue Virus, 15. Ebola; all from the 'poor' category. The results were supportive of the first hypothesis; health infographics that applied more design principles were more positively received by users (Figure 3.1).

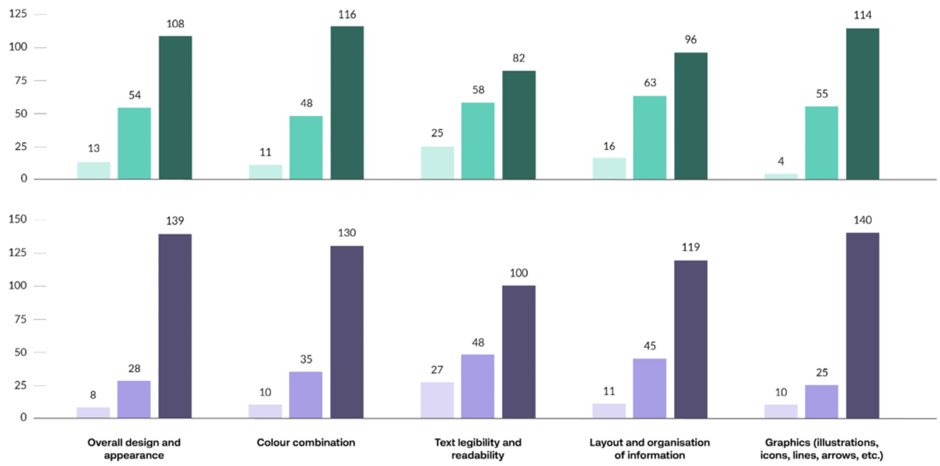
When comparing the results of the designers and the general public, opinions on the graphs appear to be similar. The designers, however, were more critical of the infographics they viewed than the general public across the majority of designs. This could be explained by the designer's experience with design guidelines and their application; this knowledge allowing designers to understand features that can better an infographic, leading to increased criticism of designs that do not utilise certain theories and principles. Despite this, both groups appeared to interpret the infographics in similar ways, the patterns in the opinion graphs are comparable (Figure 3.1).However, the general public response to the 'average' designs was more positive than expected; suggesting that median level design principle application still leads to positive design interpretation by this demographics. Despite this, the 'good' infographics were still more positively received.

‘GOOD’ DESIGN

Infographics 1-5 were categorised as ‘good’ infographics based on their application of the infographic principles. Health infographics that applied over 80% of the 84 infographic principles were considered ‘good’.

The green graphs represent the results from the designers group, the purple graphs represent the reults from the general public.

Key	Poor	Satisfactory	Good
Designers			
General public			



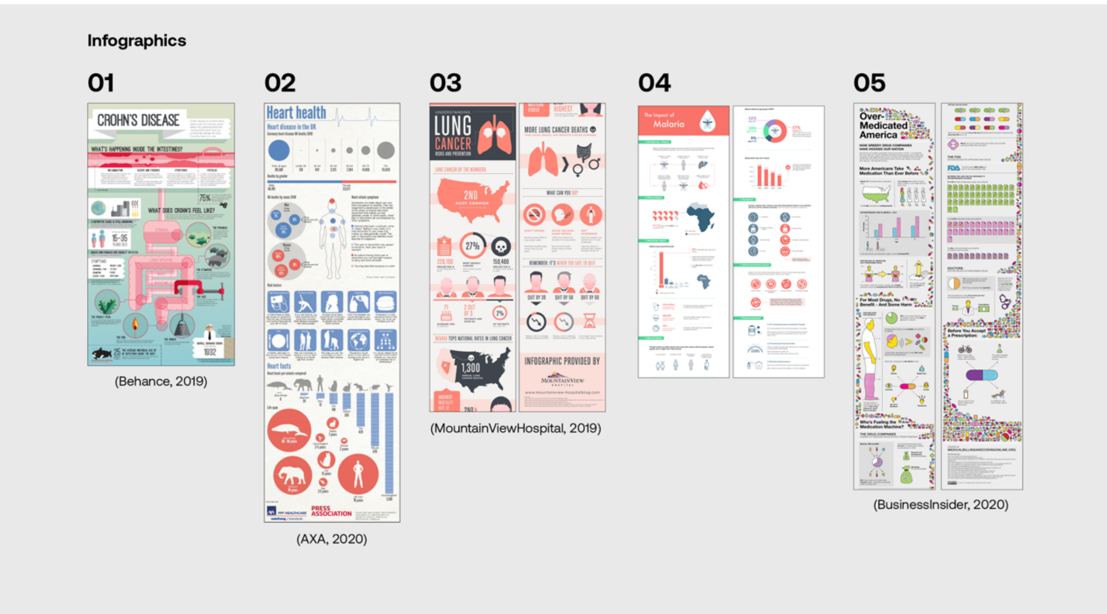
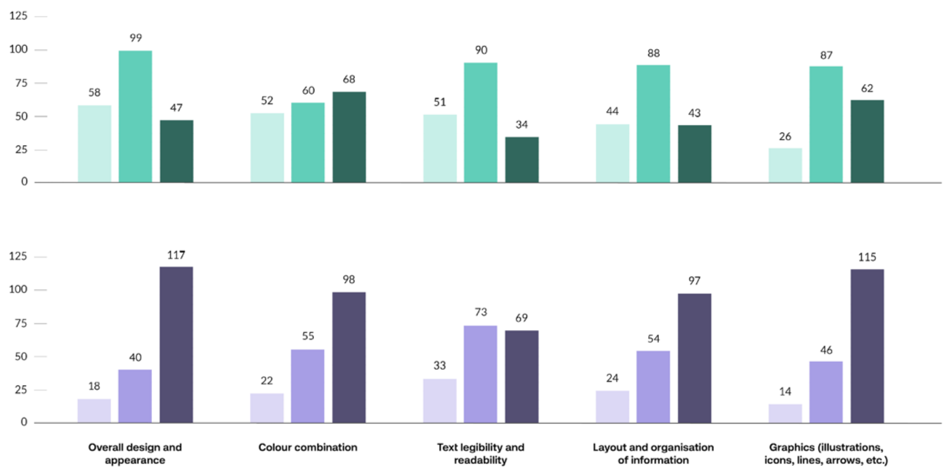


Figure 3.1. Displays the results from the existing public health infographic questionnaire

‘AVERAGE’ DESIGN

Infographics 6-10 were categorised as ‘average’ infographics based on their application of the infographic principles. Health infographics that applied between 40-60% of the 84 infographic principles were considered ‘average’.

The green graphs represent the results from the designers group, the purple graphs represent the reults from the general public.



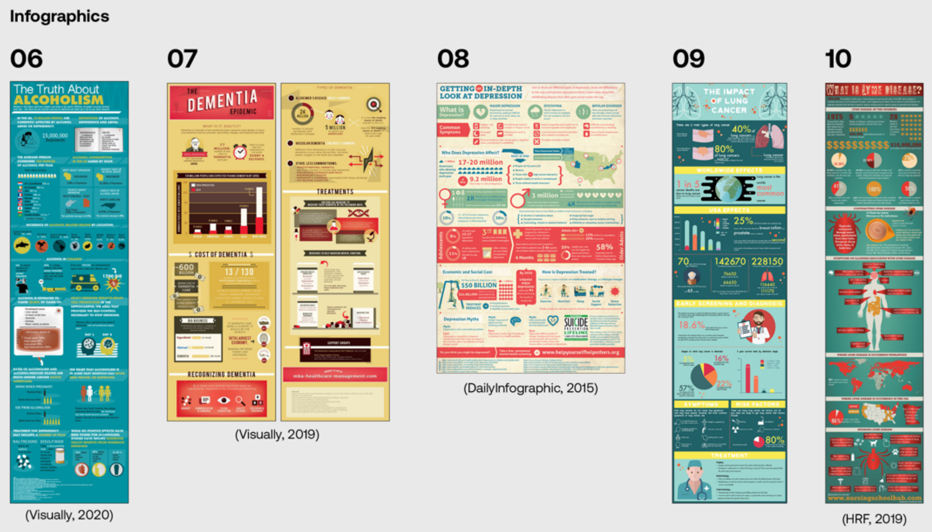


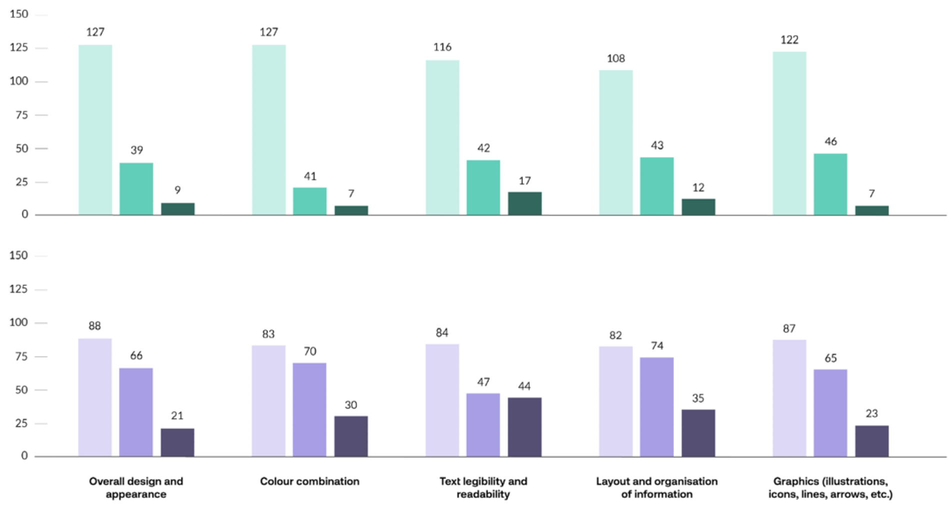
Figure 3.1 (cont.). Displays the results from the existing public health infographic questionnaire.

‘POOR’ DESIGN

Infographics 11-15 were categorised as ‘good’ infographics based on their application of the infographic principles. Health infographics that applied below 20% of the 84 infographic principles were considered ‘poor’.

The green graphs represent the results from the designers group, the purple graphs represent the reults from the general public.

Key	Poor	Satisfactory	Good
Designers			
General public			

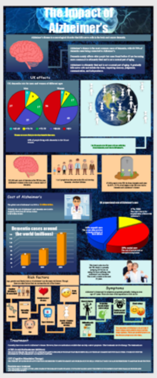


Infographics

11

(Visually, 2018)

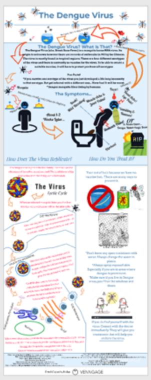
12



13

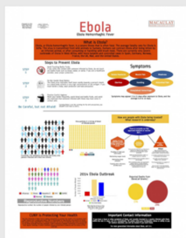
(InfographicNow, 2019)

14



(Venngage, 2019)

15



(Holtzman and Erb-Medina, 2014)

Figure 3.1 (cont.). Displays the results from the existing public health infographic questionnaire.

3.2.4. Opinion results – 'Poor' infographics

The designers were asked to express specific design problems they recognised on infographics they rated as 'poor'. The main focus of criticism was the layout. The poor infographics were considered cramped and disorganised with small margins, as well as lack of whitespace. The text was also thought to be too small and too many variations of typeface style being a common problem. A large variation of poor text design features was listed including: capitalised text, lack of hierarchy, inconsistent alignment and poor line spacing. The poor-quality or complete lack of colour scheme was another common complaint, with too many colours and low background/text colour contrast that reduced text legibility. Graphics were also considered poor quality or too complex with an inconsistent style.

Similar opinions were expressed by the public. The main problem described was the layout, which contained too much information with a crowded appearance that made them hard to follow. The second most common issue expressed was the poor colour scheme with infographics that were too colourful. The text was also said to be too small and hard to read, and the complex backgrounds used distracting. They also found the meaning of the graphics unclear and of poor quality or inconsistent in style. They also disliked the use of realistic or complex imagery.

3.2.5. Opinion results – 'Good' infographics

The designers were also asked to express specific design problems they recognised on infographics they rated as 'good. The most common feature recognised was the effective colour palettes, using 3 or less complimentary colours. Some identifying the use of a highlight colour to emphasise important information. The layouts were said to be easy to navigate and locate information, with effective chunking of information and purposeful use of whitespace. The graphs were described as engaging with a consistent style. Text was also thought to be clear using appropriate typeface styles.

Again, opinions from the public were similar. The most common feature discussed was the effective use of colour, with complimentary schemes. They also thought that the ‘good’ infographics were concise with a simple and consistent style. The layout was thought to be logical and the graphics use simple and well designed. A few participants also commented that the graphics were designed to be accessible, and could be understood despite a language barrier. Interestingly the positive features of text were rarely mentioned; though the designs were said to be easy to read. Though the designers often referred to more advanced design techniques, the opinion of the infographic were largely comparable between the groups.

3.2.6. Results discussion

Overall, the opinions of the designers and general public appears to be similar across infographics they rated as both good and poor. Both designers and the general public and found the layout to be the largest problem in the self-defined poor infographics; as well as finding the most common quality of the good infographics being the colour application. The designers recognised the application of more advanced design techniques. Such as the use of white space, information chucking and the limitation of colour and typeface style. This is to be expected given that designers have experience in the field, despite this the results remained alike across the two groups.

The results of this questionnaire show that infographics are interpreted similarly by both the general public and designers. However, designers tend to be more critical than the general public across all 5 categories. Designers, who have more knowledge of the design theory, tended to discuss the features that made for a good or poor infographic in more specific detail. The reflected opinions from both groups show that despite a lack of knowledge on design theory, the general public interpret infographic design in similar ways to designers; suggesting the application of design theory has an effect even when the underlying principles may not be detected.

The results also suggest that the categorisation of infographics based on their application of design principles was reflective of how they were interpreted by both designers and the general public. In other words, the more infographic principles that were used, the higher the designs were rated. The support for both hypotheses encourage further examination of the benefit of utilising infographic design principles in the creation of health infographics.

3.3. Infographic design development

The results from the public health infographic opinion questionnaire showed that application of design principles positively correlated with higher perception of infographic design. Though suggestive of a meaningful relationship between the application of design principles, and the effectiveness of the design; further experimental research was required to investigate if performance is significantly improved in participants using infographics that apply more design principles.

To make this possible, infographics were designed to apply the 84 principles to varying success. 3 different infographics were created to fit the categories of 'good', 'average' and 'poor' infographics. Existing infographics that may fit these categories would not be appropriate for testing; the variation in information content would likely affect the testing results. Instead, infographics were custom designed to the categories to both apply specific principles and control for the content across all 3 designs.

Though the research did not focus on the content of the infographics, the project uses public health information as a case-study. A total of 3 content variations were developed for each infographic design. This allowed a single participant to use all 3 designs during the later testing stage, and prevented content learning from affecting the results. Consequently, the infographics displayed content describing the symptoms, prevention, treatment, statistics and impact of 3 common diseases including: lung cancer, Alzheimer's disease and malaria. The information used in the content of the infographics were collected from the following resources: lung cancer (CancerResearch, 2019; NHS, 2019b), Alzheimer's disease (Alzheimer's-Society, 2019; NHS, 2019a), malaria (NHS, 2019c; WHO, 2019). The 3 infographic designs, each with 3 content variations, can be viewed in Figure 3.2.

Figure 3.2. The 3 infographic designs ('good', 'average', and 'poor') with the 3 content variations that were developed for the purpose of later comparative testing.

The purpose of the ‘good’ infographic was to be as effective as possible, based on the design principles. Similarly, the purpose of the ‘poor’ infographic was to be as ineffective as possible. Consequently, the ‘good’ infographic design was created to apply 84/84 of the design principles. The ‘poor’ design was created to apply only 1/84 principles. This singular principle was applied out of consequence; the principle stated to avoid stacked bar charts which the ‘poor’ infographic did only because the data used did not allow for the creation of a stacked bar chart. Although the ‘poor’ design was created to be ineffective, it still had to be a realistic infographic. A design feature analysis was undertaken to help inform the design of the ‘average’ design; which was meant to represent the typical infographic. The aim of the analysis was to better understand the design features and principles that are currently being displayed in existing online infographics. Common design features would then be implemented in the design of the ‘average’ infographic to make it representative of a common infographic design.

3.3.1 Infographic design feature analysis

The aim of the design feature survey was to understand common design features used in currently existing infographics. This was used to inform the design of the ‘average’ infographic output and allow it to be representative of common design. The infographics were collected online using Google Images, the image sharing platform Pinterest and the graphic design sharing websites Behance and Visual.ly. The term ‘infographic’ was searched for and designs that fit the definition of an infographic, as defined in the introduction, were saved. Randomised search selection, where infographics are randomly selected from a search engine result, may have made for a more reliable selection method. Unfortunately, this was not possible as the infographic had to be of the specific format, meaning there had to be some form of manual selection process to avoid designs that did not fit the project definition of an infographic. Thus, the analysed designs were selected infographics based on three criteria. The first being that it fit the definition of an infographic defined in this project. The second, that the infographic is available for access to the general public through the internet, and the third is that the design is displayed in the English language. The content of the infographic was not used as an influencing factor in the selection process.

Overall, 56 infographics were collected and surveyed to help inform the design of the 'average' infographic. None of the infographics used in the previous questionnaire were used in this design feature survey. The infographics were surveyed for design features, as influenced by the principles that were defined in the literature review. This was divided into the same categories as in the review, covering: cognitive and Gestalt theory, colour, layout, typographic and graphic design.
The analysis looked to collect detailed information about design features, so some principles were surveyed to collect specific details of a design feature. For example, a colour principle states to not use more than 3 colours on an infographic. So, the analysis collected how many colours were used by each infographic, rather than just if the principle was applied or not. This was to allow for more detailed data collection and to better inform the upcoming design stage. Data on the cognitive and gestalt principles could not be collected in this way, so were surveyed based on the application or negligence of a principle. It is acknowledged that the cognitive and gestalt principle application assessment was subjective. The application of a principle was judged on by the opinion of the assessing researcher. There was minimal subjective assessment involved in the assessment of the colour, typography, layout and graphic design features as the survey here collected specific design details. For example, surveying the specific number of different typefaces used in an infographic.

3.3.2 Analysis results

The results of the analysis were used to inform the 'average' infographic design. This was to make it representative of commonly available infographics, as naturally these would apply some but not all of the 84 infographic principles. Design features that were used in a majority of the infographics that were analysed were therefore used in the 'average' design. The results of the analysis can be viewed in Table 3.1. Examples of the features that were applied to the design are listed below:

- Short line length.
- Sans-serif typeface with formal style.
- 7+ colours used on the infographic.
- Blue, yellow and orange used on the infographic.

- Colourful background.
- A combination of left, right and centre text justification.
- Small margins.
- Complex 2D graphs.

3.2.3 Infographic design process

The 'good', 'average' and 'poor' infographics were designed to be representative of these categories based on the effective application of the defined design principles (Table 3.2). Overall, the 'average' infographic was designed to apply 42/84 of the design principles. This was a result of the findings from the survey, as well as the purposeful aim to apply roughly half of the design principles when creating the 'average' design. This was to also make the infographic 'average' if measured by the application of design principles. It is acknowledged that there may be some principles that are more impactful than others, but without extensive experimental testing of all 84 principles this is difficult to determine. The infographics contain the same information but displayed differently based on the application of the 84 principles.

As previously stated, the 'good' infographic applied 84/84 principles, and the 'bad' infographic 1/84. The 3 design variations can be viewed in Figure 3.2. As also observable in Figure 3.2, the 3 infographics were of variable dimensions. This is because to apply the all the layout principles defined in the literature review more space was required. For example, the good infographic had to have larger margins and more white space between elements to group the sections of information more clearly.

The number of principles applied within each category also adhered to the previous thresholds that were defined for the infographic categorisation that was implemented in the infographic quality survey (chapter 3.2, pp. 91-99)

Cognition/Gestalt

Gestalt principles	
Proximity	**59 %**
Simplicity	47 %
Similarity	41 %
Enclosure	**57 %**
Continuity	13%
Figure/foreground	**73 %**
Symmetry	36 %
Focal point	41 %
Connectedness	30%

Cognitive principles	
Chunking	71 %
Highlighting	41 %
Colour coding	38 %
Spatial continuity	61 %

Typeface

Typeface style	
Serif	5 %
Sans-serif	**79 %**
Both	16 %
Formal	**73 %**
Informal	34 %

Number of typefaces	
1	13%
2	27 %
3	**48 %**
4	9 %
5+	4 %

Average size	
Small	14 %
Appropriate	**55** %
Large	32 **%**

Average line length	
Optimal	9 %
Short	**88 %**
Long	4 %

Colour

Main colour application	
1	0 %
2	5 %
3	16 %
4	23 %
5	16 %
6	14 %
7+	**25 %**

Main 3 colours	
Blue	**79 %**
Green	27 %
White	15 %
Grey	36 %
Black	9 %
Red	29 %
Pink	5 %
Orange	**46 %**
Yellow	**39 %**
Brown	5 %
Purple	5 %

Backgroud	
None (white)	7 %
Single colour	**54 %**
Gradient	5 %
Complex	30 %
Image	4 %

Text/background contrast	
Dark text/light back	**68 %**
Light text/dark back	**70 %**
Both dark	41 %
Both light	11 %

Table 3.1. Displaying the results of the analysis that was used to identify common design features.

Hierarchy/structure	
Text emphasis	
Bold	**70 %**
Large	**50 %**
Capitals	32 %
Colour	**45 %**
Typeface	14 %
Italics	5 %
None	21 %
Text justification	
Left	41 %
Centre	21 %
Combination	**43 %**
Layout structure	
1 column	41 %
2 columns	14 %
3 columns	9 %
Unstructured	**42 %**
Interlinear spacing	
Small	39 %
Medium	**52 %**
Large	9 %
Margins	
Small	**61 %**
Medium	30 %
Large	9 %
Heading justification	
Left	23 %
Centre	34 %
Combination	**43 %**
Heading emphasis	
Bold	**82 %**
Larger	**98 %**
Capitals	**59 %**
Colour	**59** %
Underlined	4 %
Typeface	41 %
Info order deisgn	
Lines	13 %
Arrows	2 %
Numbers	18 %
None	**68 %**

Graphics	
Illustration	
Simple 2D	57 %
Complex 2D	**70 %**
3D	11 %
Photograph	21 %
Graph	
Pie	**39 %**
Bar	29 %
Line	13 %
Pictograph	27 %
Other	18 %
None	32 %

Table 3.1 (cont.). Displaying the results of the analysis that was used to identify common design features.

Principles

	Poor	Average	Good
COGNITION:			
Signal important information	☐	☐	☑
Information chunking	☐	☑	☑
Spatial Contiguity Principle	☐	☑	☑
Reduce cognitive overload	☐	☐	☑
Reduce unnecessary cues	☐	☐	☑
Attract exogenous attention	☐	☐	☑
Attract endogenous attention	☐	☑	☑
Familiar visual representation	☐	☐	☑
Consider cognition	☐	☑	☑
Create hierarchy	☐	☑	☑
Design consistency	☐	☐	☑
Reduce visible choice	☐	☐	☑
Align information	☐	☑	☑
GESTALT PRINCIPLES:			
Proximity	☐	☑	☑
Similarity	☐	☐	☑
Simplicity	☐	☑	☑
Enclosure	☐	☑	☑
Continuity	☐	☐	☑
Figure/foreground	☐	☑	☑
Symmetry	☐	☐	☑
Focal point	☐	☐	☑
Connectedness	☐	☐	☑
TYPEFACE:			
Limit typefaces	☐	☑	☑
Complimentary typefaces	☐	☐	☑
Simple typefaces	☐	☐	☑
Large X-height	☐	☑	☑
Avoid capitalised letters	☐	☑	☑
Screen designed typeface	☐	☐	☑
Sans serif typefaces	☐	☑	☑
9-12pt type size	☐	☑	☑
55-70 character line length	☐	☐	☑
Left text justification	☐	☐	☑
1.5-2 line spacing	☐	☐	☑
Clear text Style	☐	☐	☑
GRAPHICS (graphs):			
Avoid graph backgrounds	☐	☐	☑
Avoid graph over-information	☐	☑	☑
Pictographs	☐	☑	☑
High colour contrast graphs	☐	☐	☑
Bar charts	☐	☑	☑
Avoid stacked bars	☑	☑	☑
Pie charts for percentages	☐	☑	☑
Pie chart labelling	☐	☑	☑

	Poor	Average	Good
COLOUR:			
Colour preference	☐	☑	☑
Limit colour palette	☐	☐	☑
Colour signalling	☐	☑	☑
Colour memory	☐	☑	☑
Colour coding	☐	☐	☑
High background/text contrast	☐	☐	☑
Black text, white background	☐	☐	☑
Consider colour theory	☐	☑	☑
Colour contrast legibility	☐	☐	☑
Warm colours to highlight	☐	☐	☑
Cool colours to relax	☐	☑	☑
Consider associative colour	☐	☑	☑
Careful use of red	☐	☑	☑
Consider colour in context	☐	☐	☑
Avoid complex backgrounds	☐	☑	☑
HIERARCHY/STRUCTURE:			
Consider colour dominance	☐	☑	☑
Colour contrast palette	☐	☐	☑
Warm colour dominance	☐	☐	☑
Bold attracts attention	☐	☐	☑
Type weight contrast	☐	☐	☑
Limit use of bold	☐	☑	☑
Dominant headings	☐	☑	☑
Define headings	☐	☑	☑
Make headings larger	☐	☑	☑
Heading parameter limitation	☐	☐	☑
Creatre layout narrative	☐	☑	☑
Zig-zag structure	☐	☐	☑
Consider reading pattern	☐	☑	☑
Layout grids	☐	☐	☑
Branding consistency	☐	☐	☑
GRAPHICS (illiustration):			
Content consideration	☐	☐	☑
Simple graphics	☐	☐	☑
Remove chart junk	☐	☐	☑
Original graphics	☐	☑	☑
Graphic order	☐	☐	☑
Limit style variation	☐	☑	☑
Pictogram comprehension	☐	☑	☑
Icon backgrounds	☐	☑	☑
Graphics consistency	☐	☐	☑
Proportional icons	☐	☑	☑
Representative graphics	☐	☐	☑
Graphics captions	☐	☑	☑

Table 3.2 Shows if a design principle was applied in the ‘poor’, ‘average’ or ‘good’ infographic. The (•) symbol signifies the application of the principle.

3.3.4. Usability testing

Usability testing was utilised in a formative study to refine the 'good' design before the experimental study. Usability testing is a method used to identify problems and look for opportunities to improve a design (Moran, 2019). It has previously been used to optimise the design of education websites (George, 2005; Manzari and Trinidad-Christensen, 2006; Basic, 2018), infographics (Lonsdale et al., 2019), and instructional healthcare material (Lonsdale et al., 2020a; Lonsdale et al., 2020b). These publications acknowledge the effectiveness of using usability testing to create easy to use designs (Battleson et al., 2001). George (2005) recognised that usability testing was useful in identifying weaknesses in the navigation and information labelling of a website. Also, finding that design principles such as: chunking, design consistency, keywords and effective text placement can increase usability. A user-centred design approach, utilising usability testing, has also been shown to improve the communication of health information (e.g. Lonsdale et al., 2020b). It is recommended that usability testing needs only to be conducted with 5 participants; as 85% of usability problems will be found by this number of users (Nielsen, 2000). It was completed with 6 participants: 3 male, 3 female with an age range of 23-43.

This testing was only utilised with the 'good' design to identify any major design flaws before testing, and to ensure that the design appeared to be reflective of this 'good' categorisation. Any major user issues would suggest that the application of principles was not effective in creating a successful design. The results showed that the 'good' design was effective in its purpose as there were no major design problems identified and the information was located efficiently. Some minor problems were identified leading to the redesign of certain icons, colour modification and greater clarity of sub-headings to optimise the 'good' design.

This was not used in the 'average' or 'poor' designs as the process of usability testing would likely have identified flaws that were present as a consequence of the design process that purposefully ignored certain principles. The iterative redesign process would then have improved these outputs to adjust to the user feedback. This was not desirable in this research scenario, given that the 'poor' and 'average' design were created to apply or ignore specific principles.

The usability testing with the 'good' infographic involved a task that was reflective of how the infographic was intended to be used. The purpose of infographic was to allow the user to identify and remember public health information in an engaging format. To reflect this purpose, the participants were asked 3 information location questions, the answer to which was found somewhere on the infographic. They were then asked the following questions:

1. How easy was it to find the information? (Likert scale 1-5)
   Please explain your answer:
2. How would to rate the layout of the infographic? (Likert scale 1-5)
   Please explain your answer:
3. How would you rate the typeface design? (Likert scale 1-5)
   Please explain your answer:
4. How would you rate the graphics/illustrations? (Likert scale 1-5)
   Please explain your answer:
5. How would you rate the use of colour on the infographic? (Likert scale 1-5)
   Please explain your answer:
6. How would you rate the overall attractiveness of the design? (Likert scale 1-5)
   Please explain your answer:
7. How would you suggest to improve the design of the infographic:

The aim of the questions was to investigate any difficulties the participants had when using the infographic. As previously discussed, no major issues were identified, and only some minor changes were implemented in response to the feedback (e.g. improvements to icon clarity, sub-headings and colour application). The results also suggested that the application of a high number of principles prevented any major design flaws, as was expected of the 'good' infographic design.

3.4. Infographic experimental study

INTRODUCTION

3.4.1 Introduction - Background

Infographics are becoming a common tool in the communication of public health information (Stones and Gent, 2015b) and can be useful in facilitating patient understanding and communicating key messages to the general public (McCrorie et al., 2016; Scott et al., 2016). They have been recognised as an effective way to educate the general public (Siricharoen and Siricharoen, 2018); with the background, treatment and prevention of a disease being an example of potential application (Balkac and Ergun, 2018). The presence of infographics to summarise research papers have also been found to increase user engagement with the research when compared to traditional written formats (Ibrahim et al., 2017; Thoma et al., 2018; Lindquist and Ramirez-Zohfeld, 2019); implying they make information more likely to be read. The evidence suggests that effectively designed infographics can increase knowledge acquisition (Lonsdale et al., 2019) and engagement compared to text-based information. Here, an infographic is defined as a graphic design that combines text, images, and data visualisations to simplify information and describe a subject in a narrative format (Krum, 2013).

The research conducted in the use of infographics to communicate health information is limited, despite the multiple acknowledgments of their prospective effectiveness. Provvidenza et al. (2019) reported positive user support for the use of infographics in conveying educational concussion information. However, the study only compared the 6 chosen infographics through the collection of qualitative data. Chiu et al. (2015) also investigated the communication of visualised health information. Participants demonstrated high levels of knowledge acquisition after viewing the graphics. Though, as acknowledged by the researchers, the results were not compared to a sample group that received the information by a non-visualised format. Thus, conclusions about the effectiveness of the information visualisation lack certainty from both studies.

Buljan et al. (2018) reported contradictory results, finding that there was no difference in knowledge acquisition of health information when comparing infographics and text-based format of the same content; despite infographics being preferred. However, the study has come under criticism for the unknown quality of the infographics tested and the lack of consideration of potential increased engagement (Mc Sween-Cadieux et al., 2018). Contrasting experimental research has shown the effectiveness of infographics over text-based information. Lonsdale et al. (2019) found superior user preference and significantly better learning performance with participants using infographics, created in consideration of design theory, when compared to a written format.

The current evidence suggests support for the use of infographics as an engaging format to communicate public health information (Siricharoen and Siricharoen, 2018). Thus, infographics may be an appropriate method of communication for COVID-19 information during the current pandemic. This practise is already taking place; with the World Health Organisation publishing COVID-19 related infographics online (e.g. WHO, 2020). Despite their already existing use in displaying public health information, primary research in this context is undeveloped. This research looks to explore design practises for improving infographic design in the context of public health information, through the use of infographics designed in accordance with research-based design principles.

3.4.2 Introduction - Limitations of existing research

The popularity of infographics has led to the widespread creation of designs of varying quality. The ignorance of design principles have been observed to reduce the effectiveness of websites communicating important public information (Lonsdale et al., 2018). It has been suggested that there should be some standardisation or template development for infographics in healthcare, to ensure that they are appropriately designed (Atenstaedt, 2019). Though the development of fixed templates has limitations, the need for infographics to apply to researched guidelines has been recognised.

As acknowledged in the previous chapter, some research has previously undertaken looking to define infographic design principles to provide guidelines on how to create effective designs. To summarise, the following publications have described infographic principles:

- **Dunlap and Lowenthal (2016**) – Generated guidelines based on the rating of 20 popular infographics that were analysed using the *aesthetic learning experience framework* (Parrish, 2009; Parrish et al., 2011).
- **Stones and Gent (2015a)** – Described 7 basic principles to follow when creating infographic to communicate public health information.
- **Lonsdale and Lonsdale (2019)** – Published an extensive report with a literature review that defined 486 information visualisation design principles from both practice-based and experimental research. A section of the report focused solely on infographic design principles.
- **Mayer and Moreno (2003)** – Describe principles for the creation of "multimedia" designs; a larger category that includes infographics. They describe the principles in response to a cognitive framework that they developed that looks to explain how multimedia designs are processed in the human brain.
- **Hernandez-Sanchez et al. (2021)** – Described 12 tips for improving medical infographics, using references to previous experimental research to justify the defined guidelines.

In chapter 2 of the project an independent literature review was undertaken to describe principles that were applicable to infographics. The literature review focused on evidence based experimental research to establish the resultant 84 infographic design principles. This was cross compared with the report by Lonsdale and Lonsdale (2019) to ensure appropriate coverage was achieved. At the time of writing, no other research had been published that investigated the use of principles on the effect of health infographic design. However, research has recently been published that considers the effectiveness of design principle application on optimising visual information in other contexts.

Lonsdale et al. (2020b) utilised a multi-stage user-centred approach in the design of a patient instructional material, also designing in accordance to research-based design principles defined using a literature review. The researchers found significant benefit in designs utilising these principles when compared to existing instructional materials. As is supported by further research from Lonsdale et al. (2020a); finding participants using a redesigned patient instructional booklet located information significantly faster and preferred the design over the original material. The materials redesigned, again, using a user-led approach and the application of design principles. Similar methods were also used and observed to benefit the communication of security information to the public through redesigned webpages (Lonsdale et al., 2019). These publications provide support for applying research-based design principles when communicating information to the public. It is not explicitly clear if the observed benefit is a result of the user-centred approach of this research or the application of design principles; though it is likely to be a combination of the two. This chapter of the project focused strictly on the application of infographic design principles to investigate their potential benefit in the communication public health information.

Overall, there are multiple publications advocating for the use of infographics to convey complex information while recommending they need to be of good quality, but currently there is limited research on how this can be achieved. The field of multimedia learning has highlighted the effectiveness of research-based design principles, yet the principles are limited to cognitive research and often ignore guidelines from graphic design. Design principle application is yet to be explored in depth in the context of both public health information and infographics.

3.4.3 Introduction - Aim of the study

The research aims to investigate if the application of infographic design principles can improve the effectiveness of public health infographics.

The literature review undertaken in chapter 2 defined 84 infographic design principles; based on this, 3 categories of infographics were designed with varying levels of principles application ('good', 'average' and 'poor'). The research aimed to investigate if the adherence to infographic design principles can improve public health infographics; by comparing these 3 infographics. A mixed method approach was employed, using eye-tracking research to assess the efficiency of information location (measured by time to locate correct information and number of fixations). This was supported by the collection of further quantitative and qualitative data in the form of information recall testing, opinion questionnaire and interview data.

Eye-tracking has been reported as an useful method for examining visual designs, though the application of this method is currently uncommon in research regarding infographics and healthcare information. A review of eye-tracking research by Lai et al. (2013) concluded that it is a useful method to connect learning performance results to the underlying cognitive processes. Similar conclusions were described in a review of multimedia eye-tracking studies by Alemdag and Cagiltay (2018); also emphasising their support for eye-tracking studies as an effective research method for enhancing multimedia design (e.g. infographics). The review also provides evidence of the large number of eye-tracking studies undertaken in the field of multimedia learning. It is suggested the link between learning performance and cognitive eye processes should be explored in future eye-tracking research. Further support can be found by Mayer (2010) who reviewed eye-tracking studies that investigated learning with graphics; the author stating eye-tracking research offers unique outcomes for testing theories in multimedia learning. Eye-tracking studies have also been used previously to assess the effectiveness of infographics (e.g. Hossain et al., 2018; Majooni et al., 2018), though these studies are limited and have focused their investigation on infographic layout. Consequently, the research also collected eye-tracking data aiming to understand areas of interest and distracting features of the developed infographics. As well as gather data on the number of visual fixations, which describes the number of areas the user focused on. Hossain et al. (2018) suggested that the number of fixations is also an accurate measure of the efficiency of a visual design. This was collected to support the information location time data, and help establish why certain designs are easier or harder to locate information on.

It was hypothesised that health infographics that were designed in adherence to design principles (the 'good' infographic) would perform best as measured by user opinion, information location, number of fixations, and memorability; followed by the 'average' then the 'poor' infographic. In short, it was theorised that design principle application results in improved effectiveness of public health infographics. Here, the improvement in effectiveness of an infographic is defined as enhancing user preference, information location speed, number of fixations, and memorability.

METHODOLODY

3.4.4 Methodology - Participants

31 participants took part in the study. Participant age ranged from between 18 to 35, with a mean age of 22.2. 14 participants identified as male and 17 as female. Participants were chosen for the study if they had a non-design background and either spoke English as their first language or were fluent in English. None of the participants had previously taken part in the usability testing or preliminary questionnaire.

Participants were recruited at the University of Leeds using posters to advertise the study posted in the university campus. Upon contact with participant registering interest in the study, they were asked to answer a series of questions to establish their eligibility for the study. To be eligible the participants were required to: 1. Be over 18 years old. 2. To come from a non-design background (e.g. not studying or working in the field of design). 3. Have normal colour vision. 4. Be native or fluent in the English language. The participants were required to have a non-design background as the scope of future research aims to optimise the creation of health-related infographics, frequently being created by non-designers. Also, a participant from a graphic design background may have experience in design principles application of infographic design, so could influence the results through the favourability of design they know is purposefully applying design theory.

3.4.5 Methodology - Ethics

The subject of the infographics was of a potentially sensitive nature, covering topics such as cancer and Alzheimer's disease that are frequently fatal and among the most common causes of death in the UK (GOV.UK, 2019). Due to the sensitive subject matter, participants were asked when screening for their eligibility in the study if they were comfortable reading information related to cancer, Alzheimer's disease and malaria. Participants were also asked to avoid prior reading of the listed topics before the test to minimise the effect that may have on the accuracy performance results.

Participants were also instructed in the screening process, as well as before the experiment, that the research would be using eye-tracking technology to record their eye movement; as recommended by Pernice and Nielsen (2009). This was to provide the participant with appropriate amount of background on the experiment. Also in accordance to suggestions Pernice and Nielsen (2009), the eye-tracking technology was not heavily emphasised; as this can have adverse effects on the results due to the user being over-aware of the technology.

3.4.6 Methodology - Apparatus

The eye-tracker utilised in the experiment was the Tobii X2-60 compact. The infographics were high quality and exported at a resolution of 300ppi and displayed full screen on a 24-inch HD LED monitor with a resolution of 1920 x 1080p. They were displayed full screen with a 482-pixel border on either side, resulting in a width resolution of 956 pixels for every infographic. A mouse was used to scroll the infographics and click to move to oncoming sections.

3.4.7 Methodology – Information location procedure

31 participants were recruited, Pernice and Nielsen (2009) recommend using at least 30 users per heat map to collect representative visual data. Participants were seated in a range of 50-70 cm from the screen and the device successfully calibrated before each experiment. All instructions appeared on the screen and were repeated verbally to ensure understanding. Participants were first shown a pilot infographic for 30 seconds to familiarise themselves with the experimental process.

Next, the participants were shown the public health infographics. Overall, a singular participant was shown 3 infographics. One from each design category; 'good', 'average' and 'poor'. Each of these 3 categories had 3 content variations, being: lung cancer, malaria, and Alzheimer's disease. The content of the infographics was varied based which of the 6 groups the participant was randomly assigned to. A participant always viewed the lung cancer, malaria and Alzheimer's content in that order, but the design category varied based on their group; testing each category equally (Table 3.3).

This allowed the experiment to vary both the order the 'good', 'average' and 'poor' were shown to the participants, as well as the content between the designs. Thus, negating the potential effect of participants getting more efficient at locating information as the viewed subsequent infographics. Whilst also removing the effect of certain content being more memorable than another. The content had to change between infographics to allow for memorability testing of the design categories. Though the infographics had 3 content variations, within each design category, the location of text and graphics remained in the exact same location (Figure 3.3). This allowed for the coalition of eye-tracking results within a design category, despite the information content differing.

Group	Design order	Participant no.
1	ABC	6
2	ACB	5
3	BAC	5
4	BCA	5
5	CAB	5
6	CBA	5

A = Good design, **B** = Average design, **C**= Poor design

Table 3.3. Displaying how the participants were divided into groups based on the order of the designs that were presented to them.

During the experiment a question would appear on the screen and, once read, an infographic was displayed; participants were required to find the answer to the question in the respective infographic. A similar procedure was employed by Toker et al. (2013) to test graph design using eye-tracking. Participants were previously notified that they would later be tested on these answers so should attempt to remember them; a method utilised by van Weert et al. (2011) and Plass et al. (2014).

Once participants found the answer they were asked to read it aloud to the researcher. Only when the correct answer was located did the participant move on. There was no time limit on locating this information and 100% of participants found the correct answer. For each infographic, participants were given 3 information location tasks, for an overall total of 9.

Figure 3.3. The 3 content variations of the 'good' design showing that the information was located in the same place despite the difference in content. The orange circle indicates where the required information was found in the information location task.

3.4.8 Methodology – Questionnaire procedure

Participants then completed a questionnaire to gather their opinion on the designs. It is recommended that qualitative data is also collected during an eye-tracking study in order to support the findings of the experiment (Al Maqbali et al.; Andry, 2019). For each design, participants read 3 statements and were asked to agree/disagree it based on a 5-point Likert scale. The 3 statements were as follows:

1. The information was easy to find
2. The information was easy to understand
3. The information was attractive

Participants were asked to explain their answer in response to each statement. For each infographic they were also asked to choose 3 words from a list of 10 negative and 10 positive words to describe their opinion on the design; based on the Microsoft Desirability Toolkit (Benedek and Miner, 2002). This is a controlled vocabulary test where a table of descriptive words is used to gather easily assessable qualitative data that measures a user's aesthetic rating of a design (Moran, 2016). 20 words were chosen from the Microsoft Desirability Toolkit that could be used to describe the design of the infographics; 10 of the words were positive descriptions and the other 10 negative. The participant was asked to select 3 words from the table that best described how the infographic was designed. A method adapted from Lonsdale et al. (2019) used for a similar purpose of understanding a user's aesthetic response to a visual information design.

Lastly the participants were asked to rank the 3 designs based on which they found most effective and asked to explain their order. The aim of the questionnaire was to understand how effectively participants thought the infographics communicated information, as well as aesthetic preferences. At no point were the participants told which design was considered to be 'good', 'average' or 'poor'; instead they ranked the infographics using the content to differentiate. The aim of the questionnaire was to understand how effectively the users thought the infographic communicated information, as well as aesthetic preferences.

3.4.9 Methodology – Short-term memory testing

The short-term memory test was conducted following the questionnaire, the break between exposure to information and testing was purposeful in order to test for memory as appose to comprehension; as previous studies have also employed (Bateman et al., 2010, Obie et al., 2019). Participants were asked the same questions that they had been asked in the information location task, requesting them to recall the information they had previously located on the infographics. The participants were also asked to not guess the answer to the question if they did not know it. An accuracy score was calculated based on the average proportion of questions answered correctly using each design.

3.4.10 Methodology – Long-term memory testing

Participants were asked to answer the same questions 7 days after the initial experiment, this was designed on Google Forms and sent by email. Henkel (2012) utilised a similar method to test the memorability of multimedia information, conducting a memory test 7 days after exposure to the information. Long-term memory was also tested 7 days after initial exposure to the information in studies testing patient memory for medical information (e.g. Mcguire, 1996; McGuire et al., 2000). Consequently, a 7-day period was chosen to allow an appropriate amount of time to pass in order to measure long-term memory. Additional studies testing for the long-term memorability of visualised information have also employed a break of up to 2-3 weeks (Bateman et al., 2010, Stusak et al., 2015, Obie et al., 2019).

The long-term memory test was multiple-choice; a supported form of competence testing (McCoubrie, 2004) that is faster and easier to complete remotely. All the multiple-choice options appeared to be viable answers to the prevent participants from being able to effectively predict the correct answer. This is in accordance to recommendation by Haladyna et al. (2002) who states all options in a MCQ should be plausible answers. 3-4 plausible answers are said to be appropriate for MCQ (Haladyna et al., 2002). Therefore, the questionnaire had 5 options to choose from including a 'do not know' option. The participants were discouraged from guessing the answers so a 'do not know' option was offered if they could not remember the answer to a question. The order of correct answers is also recommended to be evenly distributed to prevent influencing the users answers (Masters et al., 2001), thus, the designed MCQ varied this order.

3.4.11 Methodology – Number of fixations

A fixation is defined as a group of gaze points (Blascheck et al., 2017) where the eye lingers on an area of information (Hossain et al., 2018). An larger average number of fixations can indicate that the layout is less efficient; the user is distracted by the design and has to expend more effort in search for the desired information (Goldberg and Kotval, 1999).

An eye-tracking study by Hossain et al. (2018) compared two information visualisations, one graph with a radial structure and one with a hierarchal structure. The performance accuracy test could not conclude which design was more effective; thus, the researchers determined that the hierarchal design was more effective through the analysis of the fixation data. They stated the lower number of fixations displayed in the hierarchal design showed it was a superior design. However, the information in the two visualisations is similar but differs in content, meaning the differences observed between the graphics could be explained by the differing content instead of the design. A flaw not appropriately addressed in the study. Consequently, the research here compared the number of fixations between the designs as a means to determine the speed of information location and support the information location time data.

3.4.12 Methodology - Questionnaire justification

It is recommended that qualitative data is also collected during an eye-tracking study is order to support the findings of the experiment (Andry, 2019). In their own eye-tracking study, Andry (2019) employed a questionnaire which included Likert scales. The questionnaire was conducted after the experiment instead of a think aloud technique during the eye-tracking. A high cognitive load stimulated by an eye-tracking study could negatively affect verbalisation (Charters, 2003), thus, Andry (2019) supports collection opinion data following the eye-tracking experiment. Andry (2019) also endorse thematic coding of the questionnaire transcript in order to understand the patterns in opinions exhibited by the participants. Al Maqbali et al. (2013) also supports the collection of qualitative data, recommending the use of questionnaires to explore any areas of difficultly the users may be having with the tested design.

This stage of research, therefore, employed the collection of both quantitative and qualitative data to best assess the effectiveness of the designed infographics. The questionnaire took place after the eye-tracking experiment and employed the use of Likert scales as an easy way to compare qualitative data. The findings were also thematically coded to interpret the themes expressed by the users.

RESULTS

Performance results between designs

3.5.1 Results - Information location time

Participants located information fastest using the 'good' design (M=60.16, SD=18.479), compared to the 'average' design (M=69.81, SD=26.023), with the 'poor' design resulting in the slowest time (M=77.23, SD=25.949). So, the information in the 'good' design was located significantly faster than the 'poor' design ($t(30)=-3.776$, $p<0.001$). No significant difference in time was observed between the 'average' and 'poor' design. See Figure 3.4.

3.5.2. Results - Number of fixations

The 'good' design had the least number of fixations (M=185.00, SD=44.269), followed by the 'average' design (M=223.06, SD=79.776 and finally the) 'poor' design (M=215.52, SD=79.041). Consequently, the 'good' design had significantly less fixations than both the 'average' design ($t(30)=-2.369$, $p<0.03$) and the 'poor' design ($t(30)=-2.317$; $p<0.03$). There was no significant difference in the number of fixations observed between the 'average' and 'poor' design. See Figure 3.5

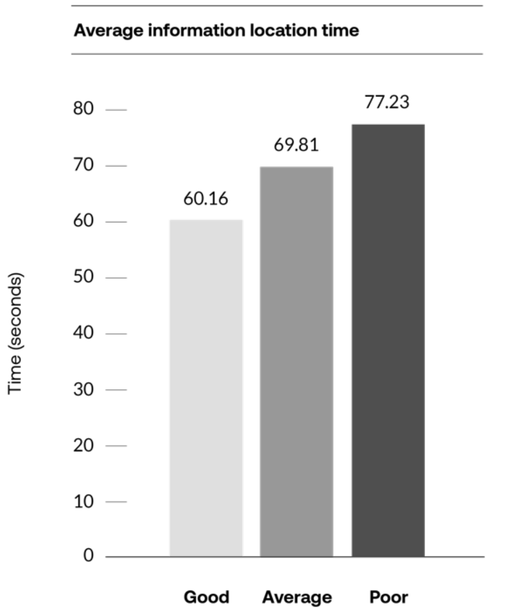


Figure 3.4. The mean time of information location task for the 'good', 'average' and 'poor' design.

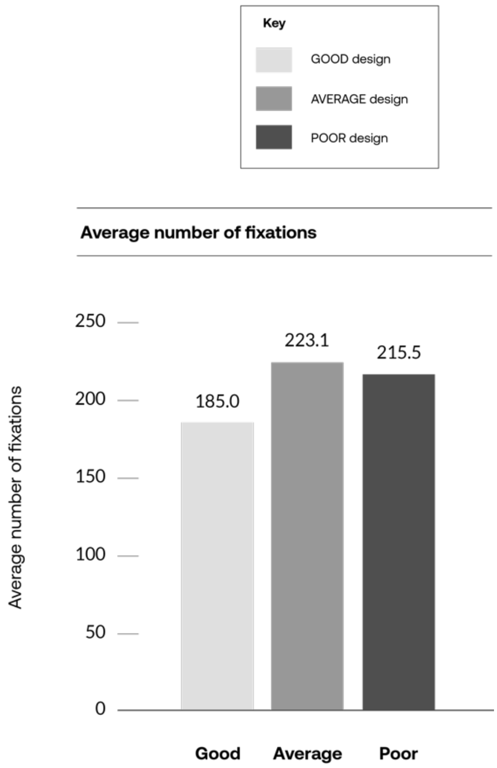


Figure 3.5. The mean number of fixations for the 'good', 'average' and 'poor' design.

3.5.3. Results - Short-term memorability accuracy

The participants performed best when recalling information from the poor design (M=0.329, SD=0.158), followed by the good design (M=0.316, SD=0.205); with the 'average' design performing the worst (M=0.252, SD=0.131). The 'poor' design performed significantly better than the 'average' design; $t(30)=-2.555$, $p<0.05$. There was no significant difference observed between the 'good' and 'poor' performance. See Figure 3.6.

3.5.4. Results - Long-term memorability accuracy

No significant results were observed with the long-term memory test with similar means being observed; 'good' design (M=0.245, SD=0.143), 'average' design (M=0.255, SD=0.143), 'poor' design (M=0.259, SD=0.157). See Figure 3.6.

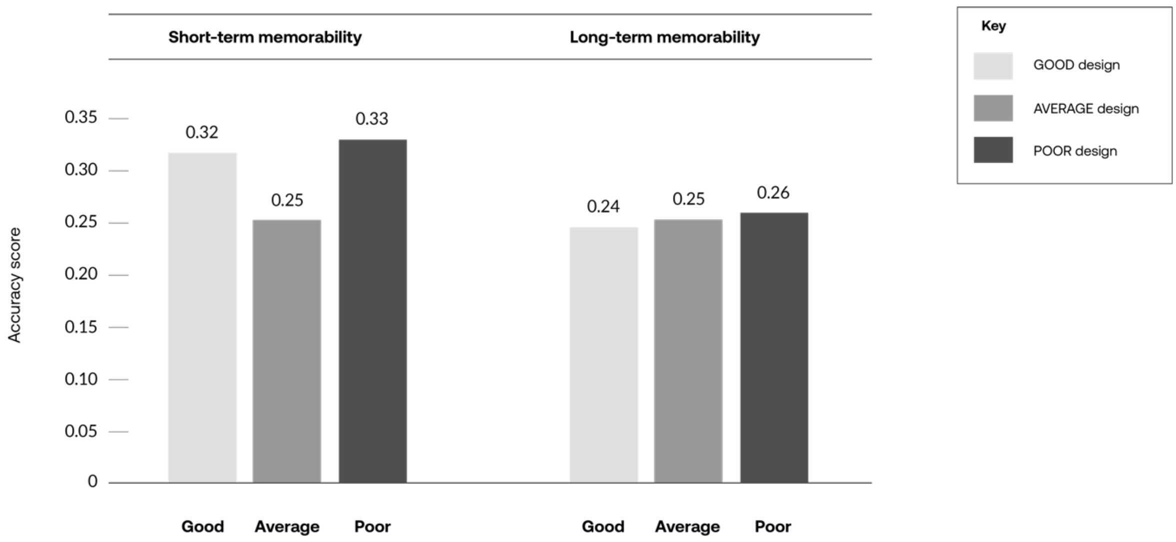


Figure 3.6. The mean memory score for the short-term and long-term memorability testing with the 'good', 'average' and 'poor' infographics designs.

Results - Qualitative results

3.5.5. Results - Preferential design

The participants were asked to rank the 3 designs based on which they found most effective; the 'good' design was most preferred with 58.1% of participants finding it most effective. This was followed by 41.9% of participants ranking the 'average' design highest. 100% of participants rated the 'poor' design as the least effective.

3.5.6. Results - Likert scale findings

Participants were asked to agree with 3 statements per infographic based on a 5-point Likert scale: 1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. Strongly agree. The 3 statements were as follows:

1. The information was easy to find.
2. The information was easy to understand.
3. The information was attractive.

Generally, the response for the 'good' and 'average' design were both positive. The participants found the information on the good design 'good' slightly easier to find and understand than the 'average' design. The 'poor' design displayed mixed results with mostly negative opinions (Figure 3.7). The majority of participants found the 'poor' design to be unattractive and the information hard to find, though it was generally agreed that the information was still understandable.

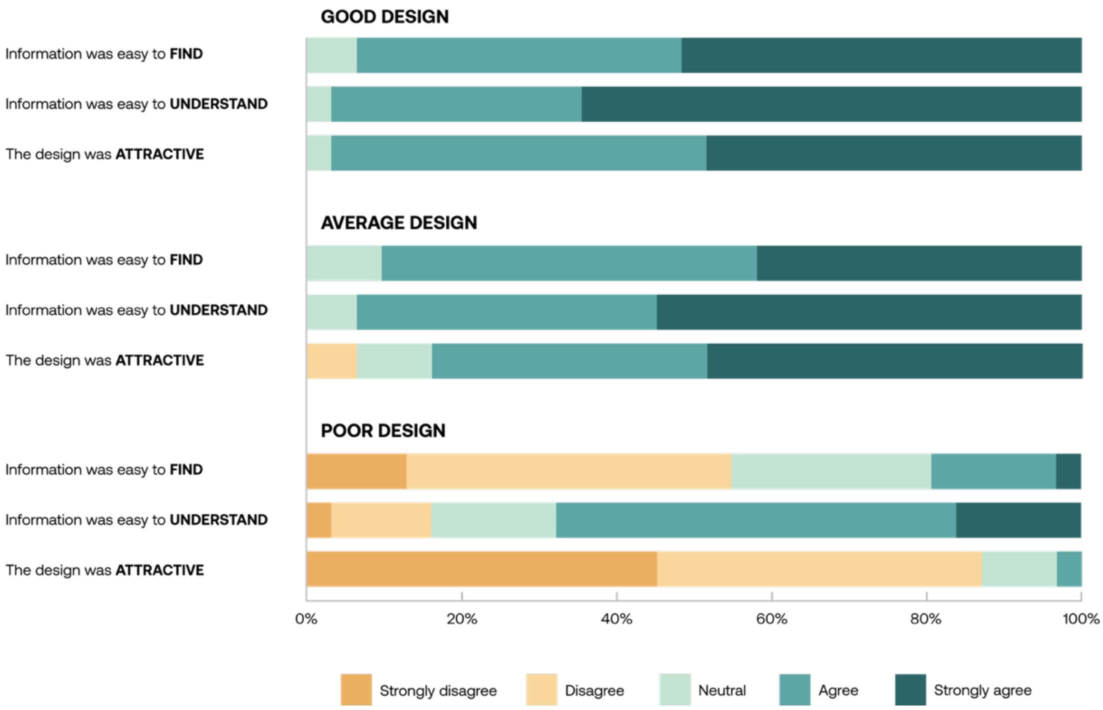


Figure 3.7. A graph displaying the Likert scale results of the opinion questionnaire for the 3 designs.

3.5.7. Results - Microsoft desirability toolkit

Participants were asked to describe their opinion on the designs, by picking 3 words from 20 words (10 positive, 10 negative) selected from the Microsoft desirability toolkit. Generally, mostly positive words were selected to describe both the 'good' and 'average' design, and negative words to describe the 'poor' design. The results are shown in table 3.4.

	GOOD DESIGN		AVERAGE DESIGN		POOR DESIGN	
+ Positive	**Clean**	**16**	**Effective**	**14**	Helpful	5
	Clear	**16**	**Clear**	**12**	Accessible	3
	Easy to use	**14**	**Straighforward**	**11**	Clear	2
	Calm	**10**	**Accessible**	**10**	Straighforward	2
	Straighforward	**9**	**Easy to use**	**9**	Calm	1
	Effective	7	Clean	8	Easy to use	1
	Accessible	6	Helpful	6	Effective	1
	Helpful	5	Calm	2	Reassuring	1
	Novel	1	Novel	2	Clean	0
	Reassuring	0	Reassuring	2	Novel	0
– Negative	Time consuming	3	Complex	4	**Dated**	**15**
	Confusing	1	Confusing	3	**Overwhelming**	**14**
	Stressful	1	Hard to use	1	**Hard to use**	**13**
	Complex	0	Stressful	1	**Confusing**	**11**
	Dated	0	Time consuming	1	**Ineffective**	**9**
	Discouraging	0	Dated	0	Time consuming	6
	Hard to use	0	Discouraging	0	Discouraging	4
	Ineffective	0	Ineffective	0	Complex	3
	Overwhelming	0	Overwhelming	0	Stressful	2
	Unhelpful	0	Unhelpful	0	Unhelpful	0

Table 3.4. The results of the Microsoft desirability toolkit word selection from the questionnaire for the 'good, 'average' and 'poor' designs. The words highlighted in grey represent the most common words chosen by participants for each design

Results of opinion questionnaire

3.5.8. Results - 'Good' design feedback

The 'good' design was interpreted positively with over half of participants expressing no negative opinions on the design and 100% expressing predominantly positive opinions.

The most common positive opinion was expressed about the colour scheme, with 17 participants (54.8%) enjoying the simple and purposeful use of colour; the colour coding of information was also recognised by 6 participants. Over half of the participants (51.6%) complimented the layout and amount of white space, finding the structure and spacing between sections of content useful in reading and locating the information. The highlighting of important information, using colour and bold text, was thought to be beneficial to draw attention. Other common useful features included headings to label sections and graphics to support textual information. Overall, the participants expressed positivity for the graphics, the simplicity of the infographic and how concise the information appeared. Some participants also stated that the design seemed appropriate to the health-related content.

A few participants expressed some negative opinions, finding the text too small, and the infographic too long by using space inefficiently.

3.5.9. 'Average' design feedback

Generally, the 'average' design was received relatively positively. 20 of the participants (64.5%) expressed both positive and negative opinions, the remaining 35% expressed only positive options on the design. The interview showed that the opinion on average design seemed to be more mixed when compared to the opinion of the good design. 20 of the participants (64.5%) expressed both positive and negative opinions of the average design, the remaining 11 (35.5%) expressed only positive options on the design.

The most common positive opinion expressed by 19 participants (61.3%) was that they liked that the important information was highlighted, the stats on the infographic were emphasised by being much larger and a different colour. However, some also expressed that the found this distracting and emphasising the wrong information. The colour scheme was enjoyed by 18 participants (58.1%) with some also liking the use of bright contrasting colours. The style and appearance of the graphics were also appreciated, finding them supportive of the textual information. The headings were useful in locating information and creating structure. Some participants thought the information concise, enjoying the column layout and the sectioning of information useful.

Some participants, however, expressed negative opinions with 10 participants (32.3%) finding the layout messy or difficult to use. Some also disliked the colours palette, finding it distracting or using too many colours. Other complaints included a distracting background, a "crowded" appearance with too much information and that the design may be inappropriate for the content.

3.5.10. 'Poor' design feedback

The majority of opinions about the 'poor' design were negative. 68% of the participants expressed exclusively negative opinions about the 'poor' design. It generally was said that though the content was easy to understand, the design itself made it difficult to access the information.

The most common negative opinion involved the ineffective structure and layout of the infographics, with 20 participants (64.5%) mentioning this in some way. The layout was said to be overcrowded and confusing, with not enough space to easily find information. There were too many colours and a clashing (or non-existent) colour scheme. The background was also distracting for over half the participants. Another common critique was that the text was too small, with many also disliking the choice of typeface; finding it distracting or hard to read. The overall design was said to be messy and lacking consistency; the appearance making it generally unpleasant to use.

3.5.11. Results - Heat maps

Heat maps were generated for the 3 designs in order to identify areas of visual attention (Figure 3.8).

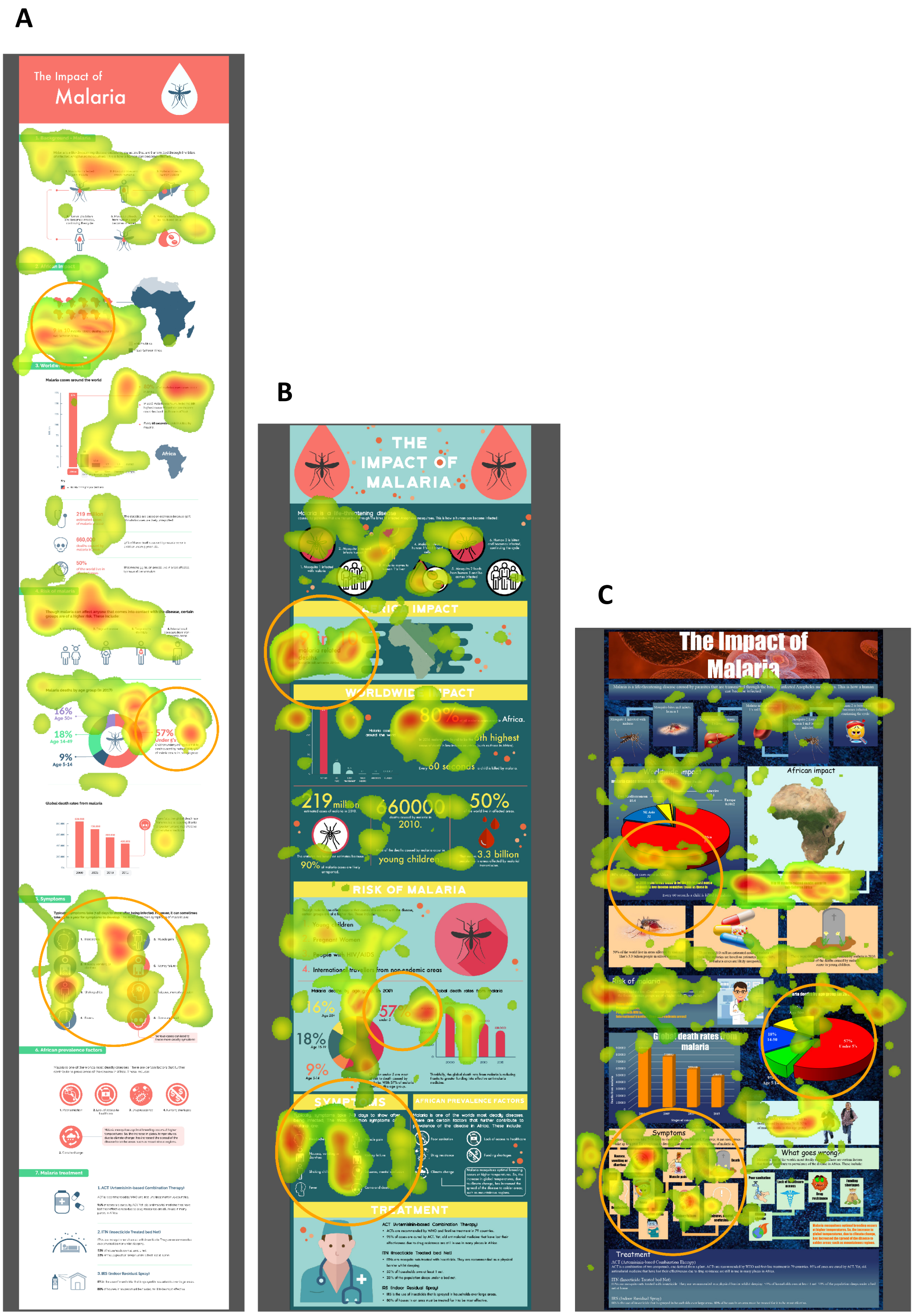


Figure 3.8. Heat map displaying the areas of interest on the (A) 'good', (B) 'average' and (C) 'poor' infographic design. The orange circle indicates where the answers in the information location task where found.

DISCUSSION AND CONCLUSION

3.6.1. Discussion – Quantitative results

Performance was measured by time (speed of information location), accuracy (of short and long-term memorability) and eye movement fixations. Overall, the 'good' infographic design was more effective than both the 'average' and 'poor' design in terms of time performance (Figure 3.4) and number of fixations (Figure 3.5). Participants located information on the 'good' design faster than on the 'average' design, and significantly faster than the 'poor' design infographic. It is important to note that participants were faster to locate information using the 'good' design despite being longer in vertical length than the other designs. The designs were the same width but, in order to apply the layout principles, the 'good' design had to longer; resulting in a length:height ratio of 1:6, the 'average' design had a ratio of 1:3.7 and the poor design 1:2.4 (Figure 3.2). Given the length of the designs they could not be displayed full screen so scrolling was necessary; also reflecting the way infographics are typically viewed online. The increased amount of scrolling required to use the 'good' design may have required both more time and cognitive effort. Despite this, the information was still located faster. The trade-off between greater infographic length and the application of principles, such as appropriate spacing and grouping, appears to be justified based on this evidence.

The only significant difference observed in the accuracy of information recollection, in terms of short-term memory, was the 'poor' design performing significantly better than the 'average' design. No other significant results were observed, though the average design performed the worst. There were no significant results observed between the designs for the long-term accuracy test (Figure 3.6). These results were unexpected and suggest that the implementation of design principles has little impact on the memorability of an infographic. One potential explanation could be that participants guessed in the recall questionnaires. This may be more applicable to the multiple-choice test (MCT) format of the long-term memory testing, that has been criticised for the option to guess and failure to recognise partial knowledge (Kurz, 1999). Future experiments looking to test long-term memory should undertake the second memory test in person or administer the test in an open question format.

A limitation of the study was that comprehension was not tested for. This could be achieved by changing the timing of the first recall test to be immediately after the participant is exposed to the infographic. Limitations in the nature of an eye tracking study made the practicality of this method of this difficult in this experiment, as the eye tracker would have to be recalibrated for every infographic viewed by a participant. However, this could have provided more detailed results regarding user comprehension that memorability data did not reveal. Another suggestion for further information design eye tracking studies is to ask more questions in the visual search task. This could have encouraged participants to use a larger proportion of the infographics and may have revealed further supporting data for the conclusions drawn in the study. Though information visualisation has been shown to increase memorability of information (Lonsdale et al., 2019), this study finds that comparing between different infographics designs does not have enough of an effect to observe differences in memorability. Further study with a more detailed information location task is required to reject or confirm the memorability findings.

There were significantly fewer fixations in the 'good' design compared to both the 'average' and 'poor' design. A fixation is defined as a group of gaze points (Blascheck et al., 2017) where the eye lingers on an area of information (Hossain et al., 2018). Together with the time performance this provides further evidence for the improvement of the 'good' design. A lower number of fixations required to find the same information suggests the design was more efficient (Goldberg and Kotval, 1999); indicating that the information was easier to locate on the 'good' design. The 'average' and 'poor' design had significantly more fixations despite being shorter in length and requiring less scrolling. Suggesting they required more visual search effort than the 'good' design to locate the same information. This result is as expected given that the 'good' design also performed faster in the information location task than both the other designs.

3.6.2. Discussion – Qualitative results

The qualitative questionnaire and interview data support the quantitative results. The 'good' design was thought to be most effective with 58.1% of participants ranking it as their favourite, followed by the 'average' with 41.9%. 100% of participants ranked the poor design lowest. The questionnaire Likert scales revealed that both the 'good' design and the 'average' design were generally positively received and thought to be attractive and understandable with information that was easy to find. The 'good' design being perceived slightly better. The 'poor' design was thought to be unattractive with information that was hard to find, though still easy to understand (Figure 3.7).

The Microsoft desirability toolkit reflected these findings (Table 3.4). Mostly positive words were selected to describe both the 'good' and 'average' design. The 'good' design was interpreted very positively with the top 5 words used to describe the design being: clear, clean, easy to use, calm and straightforward. The top 5 words for the 'average' design were also all positive: effective, clear, straightforward, accessible and easy to use. However, it is worth noting that 19.4% of participants described the average design as 'overwhelming'. Another interesting difference was that 32.3% of participants described the 'good' design as 'calm', compared with 6.5% for the 'average' design. When communicating public health information, in the content of disease outbreak, it has been recommended that this potentially distressing information should be communicated calmly (Tumpey et al., 2018). This presents a potential benefit of adhering to design principles; to calmly communicate disease outbreak information, particularly topical given the recent COVID-19 pandemic. Further research is required to confirm if a benefit is observed in this context. As expected, the 'poor' design was interpreted negatively. The top 5 words used to describe the design were: dated, overwhelming, hard to use, confusing and ineffective.

Similar outcomes were observed in interview results. The 'good' infographic was thought to be well structured with an effective colour scheme, finding the information highlighting and headings useful. The 'average' design was also said to have a good colour scheme with effective information highlighting and pleasing graphics. Though the results were more mixed with some participants finding the layout messy and the colours and highlighting of information distracting. The Likert scale results show the 'average' design was interpreted positively to a similar level as the 'good' design, however, the interview revealed that the opinion on the 'average' design seemed to be more mixed when compared to the opinion of the 'good' design. Again, the 'poor' design was interpreted as having a messy layout, too many clashing colours and typefaces and a distracting background. The qualitative results provide further evidence that the utilisation of design principles can improve the design of public health infographics; the more principles applied the more positive the user perception.

Information visualisations with consideration of aesthetic appeal have been recognised to positively impact user perception and attention (Greussing and Boomgaarden, 2019; Reyna, 2013). Heidig et al. (2015) found that a multimedia design that was perceived as more useable and attractive elicited a positive emotional reaction; leading to an increase in motivation to use the design material. Given that the 'good' design was most positively received, it would suggest the adherence of design principles results in an infographic that users would be more motivated to learn from. Currently, this link remains suggestive, and requires further research to confirm user motivation.

The heat maps generated by the eye-tracking software appear to support these results. As Figure 3.8 shows, the focus of attention in the 'good' design is consistent to where required information was located. Other areas of interest (AOI) occur but this is understandable given that the user was required to scan the entire design in order to find the required information. Also, the AOI appear to be grouped in accordance to how the infographic is sectioned with emphasis on the headings. The focused layout and lack of distracting design elements seems to have worked as intended; with users concentrating on headings and important information. The 'average' design also had clear AOI in the locations that the required information was located. However, the user attention does not seem to be as focused; AOI are placed more sporadically with attention given to unrelated graphics and statistics (Figure 3.8). The 'poor' design heatmap appears to be unfocused with AOI appearing seemingly randomly across the design; participants had to spend greater time and effort to scan through the infographic.

3.6.3. Discussion – References to previous research

The findings support the extensive work by Mayer (e.g. Mayer and Moreno, 2003; Mayer, 2010), who has published evidence of the effectiveness of cognitive principles in multimedia design. This research also endorses the more applicable research by Lonsdale (Lonsdale et al., 2019; Lonsdale et al., 2020a; Lonsdale et al., 2020b) who has found evidence for the use of design principles when communicating important information to patients and the general public. The research found supporting evidence to show the application of design principles can improve the design of public health infographics. This suggests that infographic principles grounded in research-based publications, such as those by Stones and Gent (2015a), Lonsdale and Lonsdale (2019), and Hernandez-Sanchez et al. (2021), could result in more effective infographic design if adhered to. Additionally, these results support the recommendations by Otten et al. (2015) that advocated the use of infographic principles as a valuable practice in creating successful design outputs. They also supported findings by Lonsdale et al. (2019) that recorded significantly better user performance with participants using public security infographics that were created to apply design principles, when compared to a non-visualised format.

In response to the recent COVID-19 pandemic, it has been suggested that online educational materials should be openly available through social media to clearly communicate key information to the general public (Chan et al., 2020). The online distribution of public health infographics could be appropriate as a method of communication to present information in an engaging format, as their presence has been found to increase initial engagement of scientific information displayed on social media (Ibrahim et al., 2017; Thoma et al., 2018; Lindquist and Ramirez-Zohfeld, 2019). Research has also recorded that visually attractive design is considered more usable (Tractinsky et al., 2000, Linghammar, 2007). Carefully designing infographics in adherence to design principles could encourage user engagement and improve information location of important public health information, such as COVID-19 public safety practises. The results of the study find evidence for the application of design principles in the creation of public health infographics.

3.6.4. Discussion - conclusion

The results of the study found that the application of design principles could improve the speed of information location and user-preference of public health infographics, finding partial support for the initial hypothesis. Consequently, the research recommends the application design principles in this context; to improve efficiency of information location and user perception. The applicability of the research is currently limited to those practised in creating infographics, as it would require existing design experience to effectively interpret and apply the large list of principles. This could include public health experts and information designers that create infographics. However, it is recognised that the adherence to 84 infographic design principles is time-consuming, and especially challenging to those with limited design experience. To make the findings of the study more comprehensible, the following project first streamlined the number of principles into a more efficient set of guidelines. Then developed an education tool using motion graphics to show how to effectively utilise them. This aims to make the findings more accessible to those with limited design experience.

3.7. Chapter 3 - Conclusion

The core aim of this chapter was to find experimental evidence that the application of design principles could improve the design effectiveness of public health infographics. These design principles being the 84 defined in the previous chapter. Research was first collected using an opinion questionnaire that rated the design elements of 15 public health infographics that had been categorised as ‘good’, ‘average’ and ‘poor’ based on their application of the 84 principles. The results were reflective of their categorisation with the colour, layout, typography, graphics and overall design being rated highest with infographics that had applied the most principles (e.g. the ‘good’ designs). The ‘average’ designs had a mixed reception and the ‘poor’ designs that applied the least principles had a mostly negative interpretation. This provided some evidence that infographic principle application was reflective of how the infographics were interpreted; the more principles applied the better the design was considered. The questionnaire also found that the general public interpreted the design similarly to information designers, despite their lack of experience with design principles and theory. The results of the questionnaire supported further experimental research into the effect of infographic principle application, to investigate their effect of quantitative measures such as information location speed and memorability.

To allow for further investigation, testing resources had to be developed. Original public health infographics were designed to fit the categories of a ‘good’, ‘average’ and ‘poor’ public health infographics. The ‘good’ infographic applied 84/84 of the principles, the ‘poor’ infographic applied only 1/84 principles. The design of the ‘average’ infographic was informed using a survey of common infographic design features, resulting in the application of 42/84 principles. Usability testing was used to address any design flaws in the 'good' infographic to optimise the design.

Finally, these infographics were experimentally tested in a multi-method approach to investigate the potential impact of infographic principle application. Both quantitative and qualitative data was collected in the form of information location speed, short/long-term memorability, and user opinion data; as well as eye-tracking software to support the information location data and identify viewing patterns and to understand the visual efficiency of the designs. The results found significant improvements in information location speed and visual fixation point data when using the 'good' design. Opinion results and eye-tracking patterns supported these findings with the most positive opinions and most efficient areas of interest grouping. Consequently, the study found evidence that using infographic principles can improve the design of public health infographics. The infographic design development and experimental study results discussed here have been published in the Information Design Journal (Baxter et al., 2021).

The next chapter of the project looks to find a way to allow the infographic design principles to positively impact future design of public health infographics. Making the infographic principles more accessible to non-designers could result in higher quality designs when this target audience creates their own infographics. The next chapter looks to achieve this in 2 stages. First, by reducing the number of design principles from 84 to a more practicable number. Then, developing a communication method to effectively engage and educate the target audience on how to use infographic principles.

4. Chapter 4 – Education resource development

4.1. Chapter 4 introduction

The findings from chapter 3 showed evidence that utilisation of well-established infographic design principles results in improved public health infographics. The next chapter looks to apply these findings in a practical context; to explore a method that could improve the effectiveness of public health infographics in the real world.

It is acknowledged that trained designers with experience making infographics are less likely to be creating poor quality infographics. Organisations may have an in-house graphic design team or outsource the creation of information visualisations to a separate design company. However, as shown in the introduction of this thesis; infographics of varying quality are being produced by large public health organisations such as the NHS and BMJ. Consequently, the research focuses on the education of non-designers that are more likely to be lacking design experience and knowledge. The aim will be to provide these non-designers with meaningful education, that then allows them to apply this knowledge to create more effective infographics.

4.1.1. Problem identification

A challenge was identified when assessing the realistic use of the defined 84 infographic principles. Given that the aim was to get non-designers to use the principles, the practicality of this had to be considered. As acknowledged in the previous chapter, it is unrealistic to expect an individual from a non-design background to follow 84 principles, so it was suggested that these were simplified in some way. However, even if they are simplified there is still no guarantee that they will be understood; as exemplified in a publication by Lonsdale and Lonsdale (2019) who recognised that non-designers may have difficulty following design principles.

Previous research by Stones and Gent (2015a) established a guideline of 7 essential principles that should be considered by those designing infographics in relation to public health. These guidelines were very accessible and effectively researched and communicated. However, Lonsdale and Lonsdale (2019) acknowledged that there may be a problem when using them in a realistic context. Lonsdale and Lonsdale (2019) provide an example of a publication by Scott et al. (2017) who directly reference these 7 principles to create their own infographic. Scott et al. (2016) had previously stated that healthcare professionals should be aware of infographic design, recognising infographic efficiency in communicating information and increasing research engagement. Their following publication promoted the use of infographics to maximise the impact of research publications, quoting the 7 principles by Stones and Gent (2015a) and creating their own infographic to show you how to use them. Unfortunately, the 7 principles that are displayed in their infographic were poorly understood and not applied in their own design (Figure 4.1).

Figure 4.1 Example of a poorly designed infographic from Scott et al. (2017); cited in Lonsdale and Lonsdale (2019).

As shown in Figure 4.1 shows, the infographic by Scott et al., 2017 is poorly designed despite the attempt the follow infographic principles. Clear evidence of this can be observed when looking at specific principles. A principle states to "restrict colour" which has not been achieved in the design, with the use multiple colours and an uncomplimentary palette. Another principle states to "align information", however, this is listed in a section of unaligned information. The principles have been ineffectively followed and contradict the clear guidance provided by Stones and Gent (2015a).

The aim of this project is closely aligned with those of Stones (Stones and Gent, 2015a); looking to improve the design of public health infographics through the use of essential design principles. As shown here, this may not be possible by just suppling a written list of the principles if non-designers are the target audience. Stones and Gent (2015a) display their principles in a written form with examples. To maximise the adherence by non-designers to the principles an alternative or complementary method of education appears to be required. There are 2 stages that are required to achieve this. The first is to address the number of principles. One limitation recognised in the peer-review process of the published research (from Chapter 3) stated it may be difficult to expect a user to follow 84 infographic design principles. This assessment of the principles led to the acknowledgment that the design principles need to be condensed and made more efficient. Consequently, a method needed to be developed that could recognise where principles could be combined or removed, in order to reduce the number of principles. However, it was important to preserve the most important principles whilst still making them more efficient.

Second, a design solution needed to be developed to communicate these principles. As shown, listing the principles with static examples may be an unsuccessful teaching method. Though this has not been experimentally proven, the example demonstrated by Lonsdale et al. (2019) would suggest using an alternative teaching method. A more interactive or engaging teaching method should be employed to maximise the adherence to the infographic design principles. One potential solution is to develop education motion graphic videos. This design method is addressed and justified later in the chapter.

4.2. Infographic principles reduction

The need to condense the infographic principles led to a 3-step reduction process. This resulted in a reduction from 84 to 20 principles. It is important to note that this was not achieved simply by removing 64 principles. Overall, only 26 principles were removed, the rest were combined in some way to make the principles efficient without losing potentially important guidelines. The reduction method was used to recognise both similarities in principles as well as those that were less helpful or impractical given their need to be understood by a non-designer.

The first reduction step was an analysis process that removed principles whose application was deemed impractical. The second involved a basic form of exploratory factor analysis that grouped principles that were similar into a singular principle. The third, looked to recognise the least important principles of those remaining; through surveying the principles used in high quality infographics. This process resulted in the distillation of the 84 infographic design principles to 20. These 20 principles were divided into 4 categories, to make them as easy to understand as possible. This resulted in 5 principles per category covering the following infographic design topics: colour, typography, layout, and graphics.

4.2.1. Principle reduction - Stage 1

First, a logic-based analysis was used to reduce the principles. For a principle to not be removed in this stage, all of the following conditions must NOT be applicable to the principle:

1. The principle is too subjective.
2. The principle is too general (to be implemented effectively).
3. The principle is not realistic for the target audience to follow (e.g. too complex).

This resulted in the removal of 18 principles; reducing the number from 84 to 66. An example of principle that was removed due to high levels of subjectivity includes “Associative colour - Consider common associations of a colour and utilise this, when appropriate, to link new information to prior information". It is difficult to determine if a design has been created in consideration of colour association without being involved in the design process, and this principle is based on the designer's interpretation.

The principles were also streamlined in an attempt to reduce the subjectivity of their interpretation, as well as to make them easier to understand. An example is in the "Use variation in type weight to establish a heading or title, with larger text being interpreted as having greater dominance". This principle was changed to "make the text of a heading or title bigger than body of text" to ensure their interpretation is clearer. The most subjective principles were removed during this initial stage.

Some principles were also removed due to being too general, such as "Consider cognition - Understand user and tailor design based on the application of the information with consideration of cognitive processing ". Though this is a useful principle and has the potential to improve the effectiveness of an infographic, more specific cognitive principles are required to increase understanding and to follow the principles effectively. The final logic-based method for the removal of a principle was that if principle was not realistic for the target audience to follow, then the principle would be removed. An example of this is the removal of the following principle: "Original graphics - Create original illustration, instead of applying other designer's images, to avoid unconnected or distracting imagery". It is not realistic to expect a non-designer to create high quality original illustration given their lack of experience with both digital illustrating and the software required to do so.

4.2.2 Principle reduction - Stage 2

A basic form of exploratory factor analysis was used to reduce the principles list from 66 to 40. Exploratory factor analysis can be used to determine what features are most important when classifying a series of factors (DeCoster, 1998). Factor analysis is a statistical method that looks to identify the underlying causes that influence a number of variables (DeCoster, 1998). In this context the variables are the design principles, and the aim is to find common factors in these guidelines in order to group similar principles. However, quantitative data on 84 individual design principles could not be realistically collected in the timeframe of the project. Instead, this method is used in a more basic form to describe the grouping of principles that have a common factor.

The remaining 66 principles were critically analysed to identify similarities in the principles. The analysis looked for similar vocabulary used, as well as parallel meanings with the principles. There were multiple principles that were combined, such as "Cognitive signalling - Highlight the most important information using visual cues to optimise user learning potential" and "Colour signalling - Utilise colour to attract attention and emphasise the most important information". These principles were describing very similar concepts but from different fields of design. No principles were removed at this stage, only combined if they were describing similar concepts. When combined, specific attention was given to ensure the descriptive instructions from both guidelines were preserved in the combined principle

4.2.3. Principle reduction - Stage 3

The principles were required to be further reduced from 40, as this is still a large number of principles to expect someone creating an infographic to follow. Consequently, a method was developed to help inform the further streamlining of principles. Previously conducted research looked at designer and general public interpretation of health infographics; including the judgement of the designs layout, colour, typography, graphics and overall design. The 5 infographics categorised as 'good' and positively interpreted by both groups were then surveyed using the 40 reduced principles.

A principle that was not utilised by at least 4 out of 5 of the designs was removed. It was interpreted that if a principle is not utilised, yet the design was still interpreted by both groups as being highly effective, it can be expected that this principle has reduced salience when compared to principles used by the majority of infographics. This resulted in the removal of 10 principles.

The remaining 30 principles then underwent another critical review. This involved a second round of factor analysis further combining related principles to result in a list of 20 core infographic design principles as listed below. Again, in this stage, the reduction of 10 principles did not involve complete removal of a principle. But rather, the combination of principles to create a singular more in-depth principle. An example of this is the combination of the principle “Limit typeface– Use up to 2 or 3 fonts” and the principle “Simple sans serif – Make sure type is a simple sans serif that’s easy to read”. These were combined to create the following principle “Simple fonts – Use up to 2 or 3 simple (sans serif) fonts”.

The language used in the final 20 principles was also simplified in order to make them as accessible as possible to both a designer and non-designer user. This involved changing some terminology that may be misunderstood by someone that has not studied design; for example, changing the term “typeface” to “fonts”. The sentences were reduced if necessary to make the principles as efficient yet understandable as possible. It is understood that there is potential subjectivity in the methods used to reduce the principles. However, the timescale of the project did not allow for comparative quantitative data collection of 84 individual design principles to statistically identify the most salient. Instead, this 3-stage reduction method was utilised as it could realistically conducted within the timeframe of the project and offered a more objective process than manual reduction of the principles. Table 4.1 (below) shows how the principles were combined and reduced and by what method.

Principles reduction

COGNITION:

	1. Signalling
	2. Chunking
14	3. Spatial Contiguity Principle
16	4. Reduce cognitive overload
green	5. Reduce unnecessary cues
1	6. Attract exogenous attention
1	7. Attract endogenous attention
yellow	8. Familiar visual representation
orange	9. Consider cognition
orange	10. Create hierarchy
15	11. Consistency
16	12. Reduce visible choice
63	13. Align information

GESTALT PRINCIPLES:

	14. Proximity
	15. Similarity
66	16. Simplicity
2	17. Enclosure
22	18. Continuity
orange	19. Figure/foreground
orange	20. Symmetry
1	21. Focal point
	22. Connectedness

TYPEFACE:

	23. Limit typefaces
yellow	24. Complimentary typeface
23	25. Simple typeface
red	26. Large X-height
green	27. Capitalised letters
green	28. Screen designed typeface
23	29. Sans serif
	30. Type size
green	31. Line length
	32. Left justification
	33. Line spacing
23	34. Text Style

COLOUR:

yellow	35. Colour preference
	36. Colour limitation
1	37. Colour signalling
1	38. Colour memory
	39. Colour coding
	40. Background/text contrast
40	41. Background/text colour
green	42. Colour theory
yellow	43. Colour legibility
green	44. Warm colours
44	45. Cool colours
yellow	46. Associative colour
green	47. Use of red
yellow	48. Colour in context
	49. Complex backgrounds

LAYOUT:

yellow	50. Colour dominance:
yellow	51. Colour contrast
44	52. Warm colour dominance
	53. Type weight (bold)
green	54. Type weight contrast
53	55. Limit use of bold
	56. Use headings
56	57. Use larger headings
56	58. Text size hierarchy
red	59. Heading parameter limitation
63	60. Layout narrative
green	61. Zig-zag structure
61	62. Reading pattern structure
	63. Grids
11	64. Consistency

GRAPHICS (illiustration):

orange	65. Content consideration
	66. Simplicity
	67. Remove chart junk
red	68. Original graphics
22	69. Graphic order
16	70. Limit variation
	71. Pictograms
71	72. Icon backgrounds
15	73. Design consistency
yellow	74. Proportional icons
67	75. Representative graphics
14	76. Captions

GRAPHICS (graphs):

49	77. Avoid backgrounds
green	78. Avoid over-information
81	79. Pictographs
49	80. Colour contrast
	81. Graph choice
78	82. Avoid stacked bars
81	83. Pie charts
81	84. Pie chart labelling

Key

- (n) = Combined with another principle (n = number combined with)
- green = Removed using survey
- red = Not realistic for the target audience
- orange = Principle too general
- yellow = Principle too subjective
- **Bold** = 20 principles

Table 4.1. Displaying the principle reduction method used to condense the number from 84 to 20.

4.2.4. Condensed infographic principles

The final 20 infographic design principles can be viewed below:

Layout:

1. Align elements – Align your text and graphics to create an organised appearance, this can be achieved using a layout grid (Stones & Gent, 2015; Majooni et al., 2018; Padilla et al., 2018).

2. Proximity – Placing information close together suggests it is related. Use this to group related information into a chunk (Graham, 2008; Mayer, 2009; Ali and Peebles, 2013; Gkogka, 2018).

3. Enclosure – Enclose related information using coloured shapes or outlines, this can create information chunks that makes your design easier to remember (Miller, 1956; Mayer, 2009; Patterson et al., 2014; Tetlan and Marschalek, 2016; Gkogka, 2018).

4. Noticeable headings – Use headings to divide chunks of information. Make sure they are significantly bigger and bolder than the text body (Williams and Spyridakis, 1992; Hyönä & Lorch, 2004; Kools et al., 2008; Jin, 2013; Lonsdale, 2014).

5. Connect information – Connect related chunks of information and create a purposeful reading order using lines, arrows and numbers (Graham, 2008; Ali and Peebles, 2013; Murray et al., 2017; Gkogka, 2018).

Colour:

6. Limit colour palette – Choose a complimentary colour palette of 2 or 3 colours (Mayer and Moreno, 2003; Stone, 2006; Patterson et al., 2014).

7. Clean backgrounds – Use plain light backgrounds to reduce distractions, if in doubt use a white background (Gillan & Richman, 1994; Stones & Gent, 2015; Lonsdale & Lonsdale, 2019).

8. Text contrast – Ensure colour contrast is high between the text and the background to make it easier to read (Ling and Van Schaik, 2002; Hall and Hanna, 2004; Moore et al., 2005; Buchner and Baumgartner, 2007; Galitz, 2007; Mackiewicz, 2009).

9. Highlight important info – highlight the most important words or areas of information using a colour from your palette (Schaie and Heiss, 1964; Farley and Grant, 1976; Schindler, 1986; Wichmann et al., 2002; Spence et al., 2006; Mayer, 2009; Kim, 2010; Dzulkifli and Mustafar, 2013; Jamet, 2014; Patterson et al., 2014).

10. Colour coding – Use colour purposefully to show information is related, by using the same colour for certain info (Dwyer and Moore, 1991; Worley, 1999; Mautone and Mayer, 2001; Keller et al., 2006; Mayer, 2009; Ozcelik et al., 2009; Ozcelik et al., 2010; Jamet, 2014; Richter et al., 2016).

Typography:

11. Simple fonts – Use up to 2 or 3 simple fonts, a good tip is to use one font for the headings and another complimentary font for the headings (Black, 1990; Hartley, 1994; Bernard et al., 2003; Hartley, 2004; Amdur, 2007; Josephson, 2008; Saltz, 2009; Chaparro et al., 2010; Banerjee et al., 2011; Babish, 2017; Murray et al., 2017).

12. Appropriate text size– Ensure your text is the right size; smaller than your headings but still easy to read (Tinker, 1965; Poulton, 1972; Bernard et al., 2003; Beymer et al., 2008; Lonsdale, 2014; Pušnik et al., 2016b).

13. Bold text – Use bold or capitals to emphasise important words and information, be selective with its use (Pelli et al., 2006; Mayer, 2009 Lonsdale, 2014; Macaya and Perea, 2014; Patterson et al., 2014).

14. Line spacing – Increase the line spacing in paragraphs to make your information easier to read (Ling and Van Schaik, 2006).

15. Align to the left – Make sure your lines of text fit to the left to optimise readability. (Ling and Van Schaik, 2006).

Graphics:

16. Simple design– Make you design simple and consistent, using graphics that are easy to understand (Hick, 1952; Bettman et al., 1986; Mayer and Moreno, 2003; Houts et al., 2006; Zikmund-Fisher et al., 2008; Mayer, 2009; Patterson et al., 2014; Stones and Gent, 2015a; Mollerup, 2015).

17. Avoid decoration – Remove decorative graphics and only use them if they are representing your written information (Zikmund-Fisher et al., 2008; Mayer, 2009; Gelman and Unwin, 2013; Patterson et al., 2014; Skau et al., 2015; Dunlap & Lowenthal, 2016; Lonsdale & Lonsdale, 2019).

18. Use pictograms – Use these simple forms of graphics to ensure easy understanding; avoid complex graphics and images (Mansoor and Dowse, 2003; Dowse and Ehlers, 2005; Kripalani et al., 2007; Tijus et al., 2007; McCready, 2016; Park and Zuniga, 2016).

19. Object similarity – Make objects visually similar if they are related. This can be done by matching visual elements such as colour, shape and size. (Graham, 2008; Ali and Peebles, 2013; McCready, 2016, Gkogka, 2018).

20. Appropriate graphs – If you are using graphs, ensure they are easy to understand and match your colour scheme (Spence, 2005; Hawley et al., 2008; Hildon et al., 2012; Stones and Gent, 2015a).

4.3. Education resource development

Once the principles had been condensed to 20, they were to be developed into an education resource. Information engagement and learning potential is improved when using a visual multimedia format compared to written (Snyder-Ramos et al., 2005; Höffler and Leutner, 2007; Lonsdale et al., 2019; Lonsdale et al., 2020a). So, the principles had to be developed from a written list of 20 guidelines, to a more accessible and engaging multimedia resource. Potential options for this included motion graphics, interactive website, printed booklet, online booklet, interactive infographics, or video lectures.

The visual communication method that appeared most appropriate to achieve this was the development of educational motion graphics. A motion graphic is a video using animated elements to create a sense of motion in order to communicate information, often accompanied by sound (Shir and Asadollahi, 2014). They are becoming a popular communication tool often used by embedding in website articles or on video platforms such as YouTube (Krum, 2013), as well as distribution through social media.

4.3.1. Motion graphic justification

Using motion graphic videos as the education tool for this project seemed appropriate from a practical perspective, as well as an accessible and engaging format. Videos can be easily hosted online and shared through an email link; particularly beneficial in a research project that had to be conducted online due to COVID-19 restrictions. Given the remote nature of the research, it is also easy to control the education process when using motion graphics. The participants can simply be asked to view the videos, it requires no active reading or navigation of resource such as a website. This this supported by Hsueh et al. (2016) who reported that motion graphics reduced cognitive overload resulting in a faster learning process, when compared to static graphics. Motion graphics are also easy to share online making them a good option for maximising the accessibility of the education resource outside of a research perspective. They have also been recommended as an effective learning tool in a student education setting (Wiana et al., 2018; Hapsari and Hanif, 2019).

Experimental research in motion graphic communication is limited, though some primary research in support of this form of visualisation has been published in the field of education. The publications in this field tend to use the more generalised term "video", so still exploring moving visual media but not necessarily containing animated elements. Video learning has been described as an effective means of education. Wong et al. (2019) found that video learning correlated with significantly better scoring from practical and theory assessment, with 90% of students agreeing they were helpful to develop practical dental skills. Student satisfaction also appears to benefit from video learning, with video lectures resulting in increased student engagement (Choe et al., 2019) and satisfaction (Hsin and Cigas, 2013).

Recently, motion graphic research has also been conducted in a more relevant subject; exploring their use in communicating health information. Lonsdale and Liao (2018) found that knowledge acquisition of health information, in the context of obesity, was significantly improved when educating participants using a motion graphic. Multiple stages of usability testing with the target audience of the motion graphic were utilised in order to develop a design that prioritised user experience. The results found that participants had significantly improved obesity knowledge after using the motion graphic. Finding support for the use of a motion graphic in the effective education of health information. However, this was not compared to any other form of information visualisation; though this was later addressed in subsequent research.

Supporting evidence was found by Lonsdale et al. (2019) who investigated the education of security information to the general public. They found significantly improved knowledge when using visualised information (infographics) when compared to basic written information. They also compared motion graphics and static infographics, finding no difference in the electiveness of communication; suggesting motion graphics are an equally effective method of communicating information in this context. Lonsdale et al. (2020a) also explored the use of motion graphics as a supporting education resource for medical procedure patient education. Again, an iterative user-centred approach was employed, improving the motion graphics in response to feedback from the intended users and design experts. Performance testing revealed that motion graphics displayed a significantly better comprehension accuracy compared to text-heavy instructional materials, as well as very positive qualitative data describing advocacy for this format.

Research conclusions stated motion graphics enabled efficient explanation of complex concepts that would have been difficult to replicate in a static format. Motion graphics were said to have an advantage in explaining detailed step-by-step instructions in a shorter time period, that would have required numerous explanatory pages of text in a written format. Findings also indicated that performance using motion graphics were equal across ages groups, presenting evidence to reject the claim by Strizver (2014) that younger audience perceive motion more naturally.

A study comparing information gain and patient satisfaction between a booklet and a video found supporting results (Snyder-Ramos et al., 2005). The group using the video was found to have greater satisfaction and information gain. Although the research utilised a documentary video rather than a motion graphic, the results imply enhanced learning using a video compared to a printed format. Additional support can be found in a meta-analysis of instructional information comparing motion and static graphic formats (Höffler and Leutner, 2007). The analysis revealed an advantage in using motion over static graphics, particularly when the video is content specific rather than playing a decorative role. Given that the purpose of the education resource that will be developed is to instruct the user on how to use design principles, a motion graphic appears to be an appropriate method. Höffler and Leutner (2007) conclude by stating motion graphics design should be grounded in learning and instructional theory.

4.3.2. Motion graphic principles

Learning and instructional theory has been discussed by Professor Richard Mayer in his extensive work on multimedia learning. Mayer proposed a series of research-based principles when using multimedia learning for e-learning (Mayer and Moreno, 2003). These principles were based on the reduction of cognitive load; an important consideration in the development of instruction material (Brame, 2016). As discussed in chapter 2, cognitive load theory states working memory has a limited capacity (Sweller, 1988; Sweller, 1994) but multimedia learning facilitate learning by addressing both the visual and auditory processing channels (Mayer and Moreno, 2003). Mayer and Moreno (2003) developed design principles to regulate the cognitive load during this method of learning. Those applicable to motion graphics are as follows:

1. **Coherence** People learn better when extraneous material is excluded.
2. **Signalling** People learn better when essential material is highlighted.
3. **Redundancy** - People learn better from graphics and narration that from graphics, narration, and on-screen text
4. **Spatial Continuity** - People learn better when on-screen words are placed next to the corresponding part of the graphic.
5. **Temporal continuity** - People learn better when corresponding narration and graphics are presented simultaneously
6. **Segmenting** - People learn better from a multimedia lesson when words are presented in spoken form.
7. **Segmenting** - People learn better when a multimedia lesson is presented in small user-paced segments.
8. **Personalization** - People learn better when the words in a multimedia lesson are presented in conversational style rather than formal style.
9. **Voice Embodiment** - People learn better from a human voice than a machine-like voice.

It has been observed that videos that closely aligned with the multimedia principles defined by Mayer and Moreno (2003) resulted in videos with high satisfaction ratings. A publication by Brame (2016) further explored these multimedia principles in the context of video learning for students. They addressed three elements of learning in video design: cognitive load, student engagement, and active learning. Brame (2016) conducted a review of the literature within these fields and established a series of guidelines for the development of educational videos. Although the publication uses the more general term 'video' some of the guidelines are still applicable to motion graphics. Those both not previously covered, and applicable to the motion graphic that will be developed are as follows:

1. Use key words on screen to highlight important information.
2. Divide topics into individual videos and make them short (less than 6 minutes).
3. Remove complex backgrounds.
4. Narrate the animation; speak relatively quickly and with enthusiasm.
5. Use conversational language (e.g. 'your' instead of 'the' to create social partnership between the instructor and user).

Further principles of motion graphic design were established by Lonsdale and Liao (2018) in their publication. These were utilised in the design of their own education motion graphic that was shown to significantly improve knowledge acquisition of their subject matter. Consequently, these principles will be adhered to in the design of the educational videos created during this project; in an effort to maximise knowledge acquisition of infographic design principles. The following principles are:

1. Avoid excess movement, high speed, motion effects for type in motion.
2. Avoid too much text in the same frame.
3. Use sans serif typefaces to maximize legibility.
4. Consider the conceptual interplay between typography, voice over and images.
5. Carefully select colors for type and graphic elements in order to create sufficient contrast between elements, and between elements and background.
6. Use color to differentiate levels of meaning and significance.
7. Emphasize information by manipulating time (slowing or speeding it up).
8. Illustrate the relationships amongst different pieces of information.
9. Direct viewers to selected pieces of information in order to help minimize misunderstanding.
10. Use language and sound to support or emphasize the graphic elements, as well as establish a personal connection with the viewer.
11. The viewer has a limited amount of time available to perceive the content, and different viewers perceive information at different rates.
12. Sequences that are too long will tire the viewers.
13. Consider established principles of motion design (e.g. timing, anticipation, staging, exaggeration, secondary action, squash & stretch, etc.)
14. Use motion as a design tool to support usability.

These principles are quoted directly from Lonsdale and Liao (2018), who references the following publications in the establishment of these motion graphic design principles: (Lasseter, 1987; Tufte, 2004; Finke et al., 2012; Strizver, 2014; Pannafino, 2015; Stones and Gent, 2015a; Landa, 2016; Willenskomer, 2017).

Motion graphics appear to be an appropriate method of user education, potentially increasing engagement and learning potential. Consequently, they will be utilised to teach the target audience on how to use infographic principles when creating their own designs. When designing the motion graphic videos, the principles established in these 3 publications will be carefully considered and applied during the design process of the education motion graphics to maximise this potential benefit.

4.4. User centred design approach

User centred design (UCD) describes a design process that involves the target audience throughout the process to create an accessible and usable design outcome (Abras et al., 2004). UCD is reported to improve usefulness and ease of use of the designed output (Vredenburg et al., 2002). Usability testing, iterative design and user requirement analysis have been considered 3 of the most important UCD methods (Vredenburg et al., 2002), all 3 were implemented in the design process of the motion graphics.

4.4.1. USD methods

An iterative design process was employed to generate a design output that address the needs of the target audience. Iterative design is a prototyping where design prototypes are tested and design problems addressed in multiple stages before publishing the final design (Nielsen, 1993). Combined with UCD the process implements feedback from the target user in multiple stages, creating a tailored motion graphic output.

One common UCD technique, and the one used in this process, is usability testing. This is an observational technique aiming to identify problems in a design by getting participants to perform realistic tasks that reflect the purpose of the design (Moran, 2019). This process of redesigning in multiple stages, based on user testing, is recommended by Nielsen (1993) who states it can substantially improve usability.

4.4.2. Usability testing

The use of usability testing has been shown as an established method of design development in the creation of websites (e.g. Dickstein and Mills, 2000; George, 2005; Manzari and Trinidad-Christensen, 2006). Becker and Yannotta (2013) recorded that usability testing was an effective method to design a website that reflected the user's requirements. Finding further evidence for the use of usability testing in the development of user-centred design. Usability testing is becoming a more common research method for problem identification during information design processes. Brooke et al. (2012) used usability testing to highlight multiple issues with a patient hearing aid instruction booklet. The participants were divided into 2 groups to test 2 booklets and asked to complete common hearing aid tasks based on instructions from the booklets. Missing information, diagrams, layout, and content difficulties were identified during the testing. However, usability testing was conducted with 40 participants in only a single stage. Using an iterative approach where multiple rounds of usability testing were employed with less participants may have resulted in additional problem identification. The authors did not use the findings to design an improved booklet, instead they expressed the need to evaluate information resources prior to their use.

Usability testing has also been utilised to improve information design outputs. Research by Lonsdale et al. (2019) also found support for the use of user-centred information visualisation in the education of security information for the general public. Information from the MI5 website was found to be significantly improved when redesigned using visual information techniques, when compared to its original text-based format. This publication also compared the effectiveness of infographics and motion graphics, finding no difference in communicating information in this context. Multiple stages of usability testing were employed throughout the design of the public security information motion graphic.

This was further supported in the context of patient health information, looking specifically at a booklet to prepare patients for a colonoscopy procedure. Lonsdale et al. (2020a) compared an NHS colonoscopy preparation booklet with a redesigned booklet and motion graphic, both created with a user-centred approach. The newly visualised information from the redesign booklet significantly improved the comprehension and location speed of information. The motion graphic was also found show greater improvements in comprehension compared to the redesigned booklet. This supports the idea that motion graphics would be an appropriate education tool, along with further support for a usability testing development process from both research publications.

A similar study also showed auxiliary results (Lonsdale et al., 2020b). A more extensive bowel surgery preparation booklet was again designed with a user-centred approach, visualising information using icons and infographics. The comparative study tested the original and redesigned booklet; finding significantly improved accuracy of information and speed of information location with the redesign material. The redesign was also much more positively received in the subsequent opinion questionnaire. This publication found further evidence for the use of a co-design solution. The redesigned material was designed with multiple stages of usability testing with the intended target user of the material, looking for flaws in the design that could be improved. As well as interviews with medical experts to advise from a health-based perspective. The co-design development should not be undermined, as this likely also contributed to the significantly improved redesign. The research went on to develop an education website, in accordance with previous patients who expressed that a website was the most appropriate companion output to the booklet. Again, usability testing was utilised to inform the improvement of the design. Users accurately located information and found the website both helpful and easy to understand.

4.4.3. User requirement analysis

A final UCD method that was employed was user requirement analysis. User requirement analysis is a collection of methods used to establish the needs of the target user before the designing takes place (Maguire and Bevan, 2002). Interviews are a common user requirement analysis method (Maguire and Bevan, 2002). This analysis took place as an initial investigation to inform the design of the initial prototypes.

The needs of the user in this context are to learn how to improve the design of their infographics. To achieve this, they will be educated on how to use infographic principles when creating their own designs. Given the probable lack of design experience of the user, the education resource must be developed to ensure the principles are simple and understandable. Healthcare professionals will likely have a degree level education, so the resource should be easy to use without appearing condescending to the educated target user.

Informal interviews were undertaken with a group of medical doctors to understand what the most appropriate form of media that the education resource should take. The users thought a digital format would be most appropriate to allow for easy access and storage. They also thought that it should be something engaging to hold their attention, and not just feel like a written list of instructions. The users also expressed that working in a healthcare profession often came with long working hours and shift work, so a resource that was time efficient in its teaching would be ideal. Based on the feedback a either a website or motion graphic videos seems an appropriate design solution. Motion graphics, however, may be easier and more efficient to use due to the lack of navigation and active information searching required. This, alongside the supporting literature, influenced the decision to develop motion graphics videos as the education resource format.

4.4.4. Score-based design assessment

Score-based methodologies have been developed that can be used as problem identification for instructional materials. One that considers the design features of the material, as appose to just the content, is the Suitability Assessment of Materials (SAM). SAM was a method developed for the evaluation of health-related information for adults by Doak et al. (1996). The material is rated in 6 keys areas that include: 1. Graphics, 2. Layout and type, 3. Content, 4. Literacy demand, 5. Learning stimulation and motivation, 6. Cultural appropriateness. Multiple factors are rated within these categories with a score from 2 to 0, these scores correspond to: 2. Superior, 1. Adequate, 0. Not suitable. For example, within the graphics category the assessors are asked to rate the illustrations. To get a 2 (superior) score the illustrations have to be both: 1. Likely familiar to the adult user, and 2. Simple illustration that is appropriate to a user. If only 1 of these factors are met it receives a 1 (adequate) score. If none are met it receives a 0 (not suitable) score. It functions as an overall checklist of 22 scoring criteria within 6 categories.

Support for the method has been observed. Morowatisharifabad et al. (2020) used 20 reviewers to assess post-menopausal behaviour material. They did not use the method as a problem identification method, but to judge the effectiveness of the material before and after it had been "tailored" to the target user. They found significant increases in SAM scores for the "tailored" material. McMullan et al. (2018) used SAM as a means of problem identification. They revised hearing aid user guides using results from the SAM assessment, finding significant improvement in performance in a utility task when using the revised material. Hoffmann and Ladner (2012) also used SAM to assess written stroke material. The purpose of the study was to assess the reliability of SAM scoring, using 2 assessors and comparing the results. The majority (17 of 22) were reliably scored, though the more subjective scoring descriptions resulted in uncorrelated grading. They conclude that SAM is valuable in identifying issues in education materials, but caution should be exercised in interpreting subjective categories.

Much like the purpose of usability testing, SAM can be used as a method to identify problems in the design of instructional material. However, this assessment method does not always involve the feedback of the target audience. Instead of using the target audience to identify real problems with the material, it relies on judgement from an outside assessor. The assessment is partially based on the assumption that the user will also experience the same problems identified by the assessor. However, studies have also used the target user to complete the SAM assessment (e.g. Morowatisharifabad et al., 2020). Unfortunately, this still limits feedback to the parameters of the assessment scoring, instead of allowing for more detailed problem identification and improvement opportunities.

A further criticism of the methodology lies in the subjectivity of the assessment process; the category scoring is based only on the opinion of the assessor. Yet, it is acknowledged that subjectivity is often difficult to avoid in design assessment. From an information design perspective, the method appears to have a restricted assessment of certain features too; with limited of consideration colour application or information separation and grouping techniques. Score-based assessment techniques, such as SAM, may not be suitable for the assessment of information design outputs. Based on the greater support and more detailed user data collection, usability testing appears to be a more appropriate methodology to inform the design of the education resource.

4.4.5. Design approach summary

The research here, therefore, supports the use of visual communication to communicate information; as well as the use of a user-centred design development process. Evidence also exists in support motion graphics as an education tool. Thus, this education tool will be developed as a set of motion graphic videos that will go through multiple stages of usability testing, as previous research has found clear evidence of the benefit of user-centred design (Lonsdale and Liao, 2018; Lonsdale et al., 2019; Lonsdale et al., 2020a; Lonsdale et al., 2020b). The videos will aim to be attractive and functional, whilst being designed to meet specific needs of the user and the education objective of the resource.

4.5. Motion graphic development

4.5.1. Prototype development

The videos were created in 2 initial stages. First, the static elements for the videos were created; this included the infographics used in each video. Each video had a unique infographic that was improved in 5 stages as the principles were applied throughout the video. These infographics were created using Adobe Illustrator to create any illustration and graphs, and Adobe InDesign to arrange the elements and text to create the infographic. The 4 infographics can be seen in Figure 4.2. Each infographic was used in only one of the 4 videos covering layout, colour, typography, and graphics. The subject of the 4 infographics was as follows: 1. Sepsis (layout), 2. Vaccines (colour), 3. Stroke (typography), 4. Alcohol abuse (graphics). The public health information used in the infographics was collected from the following sources: sepsis (Healthline, 2021b ;NHS, 2021c), vaccines (NHS, 2021e; PublicHealth, 2019), stroke (NHS, 2021d; StrokeAssociation, 2021), alcohol abuse (Healthline, 2021a; NHS, 2021a). When designing the infographics careful consideration was made to apply the 20 infographic design principles.

The developed infographics were then assessed by Professor Maria Lonsdale, an expert in the field of information design. Changes were made to ensure that each of the 4 infographics had a unique design. Suggested improvements to infographics also resulted in the following alterations to the infographics: improved text colour contrast, higher quality illustration, layout alterations, colour palette improvement, and typeface size increase.

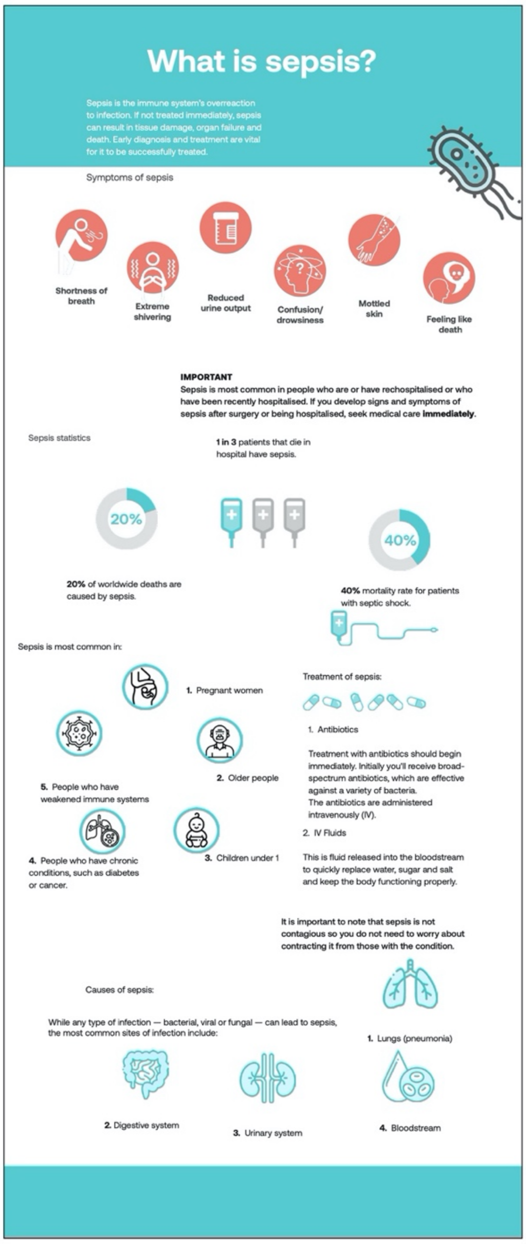
After the infographics were finalised, it moved on to the design of the videos. The videos were animated using Adobe AfterEffects. The principles previous defined by Mayer and Moreno (2003) Brame (2016), and Lonsdale and Liao (2018), were again taken into careful consideration during the design process; being consulted multiple times throughout the design process to ensure adherence. Once the animation was created, a script was developed for the voiceover and recorded using GarageBand. The animated video, the voiceover and the background music were arranged to create the motion graphic using Adobe Premiere Pro.

Each video consisted of 5 principles, divided into the categories of layout, colour, typography and graphics. The 4 infographics that were developed were assigned to one of the video categories. They were then negatively altered to not apply the 5 design principles of category they were assigned. Next, the infographics were improved back to their original design by applying the 5 design principles in a 5-step process. This was screen recorded whilst using the Adobe InDesign software to create the 'example' sections that can be observed in the motion graphic videos. The infographic before and after applying the 5 principles from their category can be viewed on Figure 4.2.

The 4 videos followed the same format. First, an introduction section was animated that provides context for the video and explains what will be covered, including the 5 principles. Next, each principle was described in greater detail along with the 'example' recordings that showed the user how to effectively utilise the described principle. Each 'example' was followed by a section that displayed the infographic before and after the principle was utilised. This was to further help the user to understand how to use the principle. Lastly, a final summary section was created as an overview of the 5 principles covered and how this impacted the design of the infographic. Once the first video was fully completed, this was taken to the first stage of the usability testing.

1. LAYOUT INFOGRAPHIC

Before



After

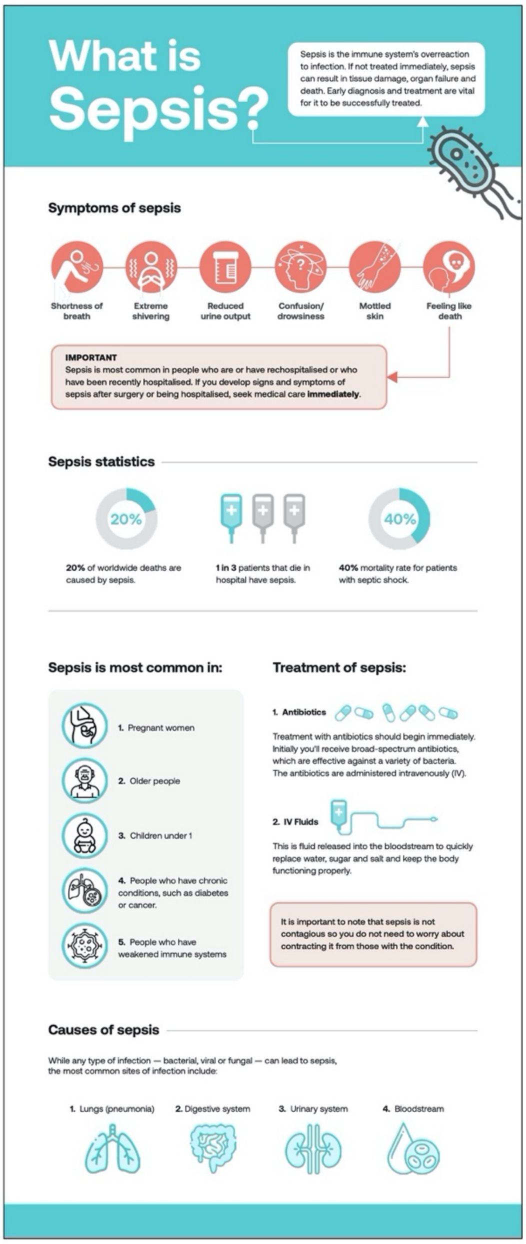
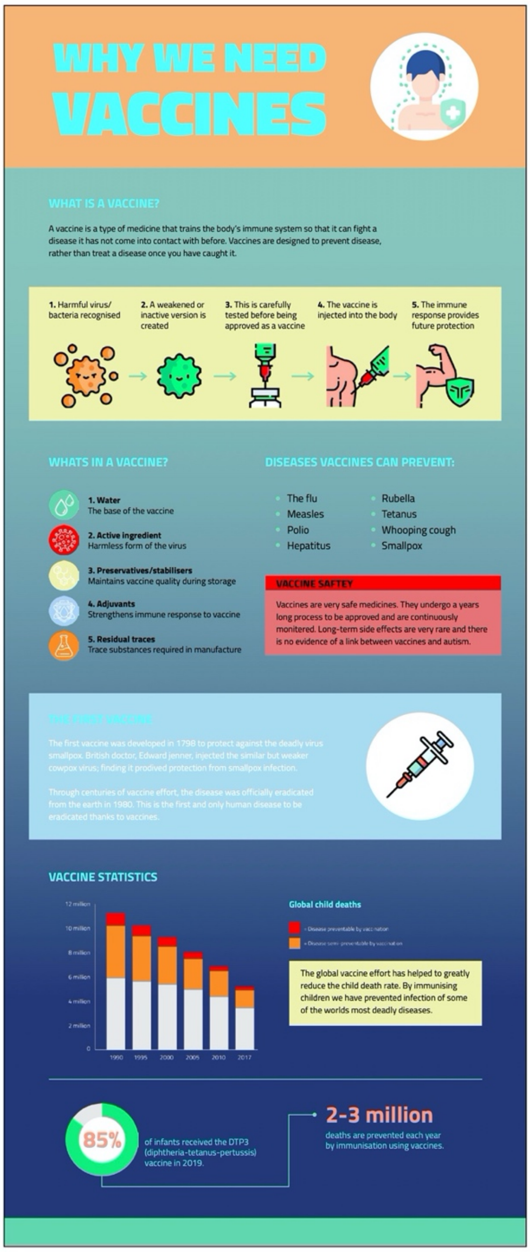


Figure 4.2 The designs that were created and used within the motion graphics videos to display the infographic 'before' and 'after' applying the principles discussed in the video.

2. COLOUR INFOGRAPHIC

Before



After

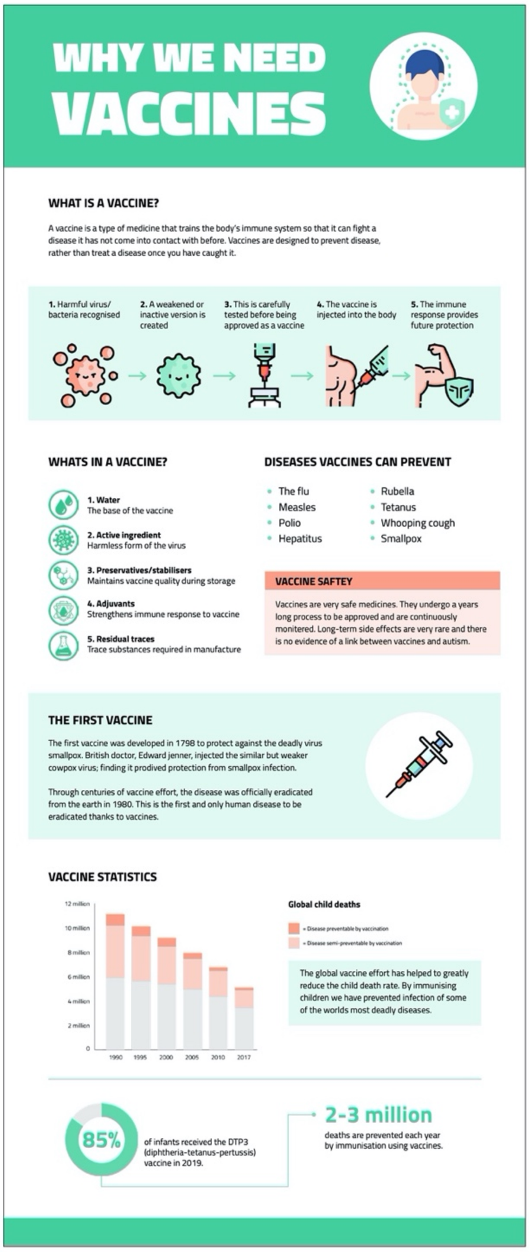
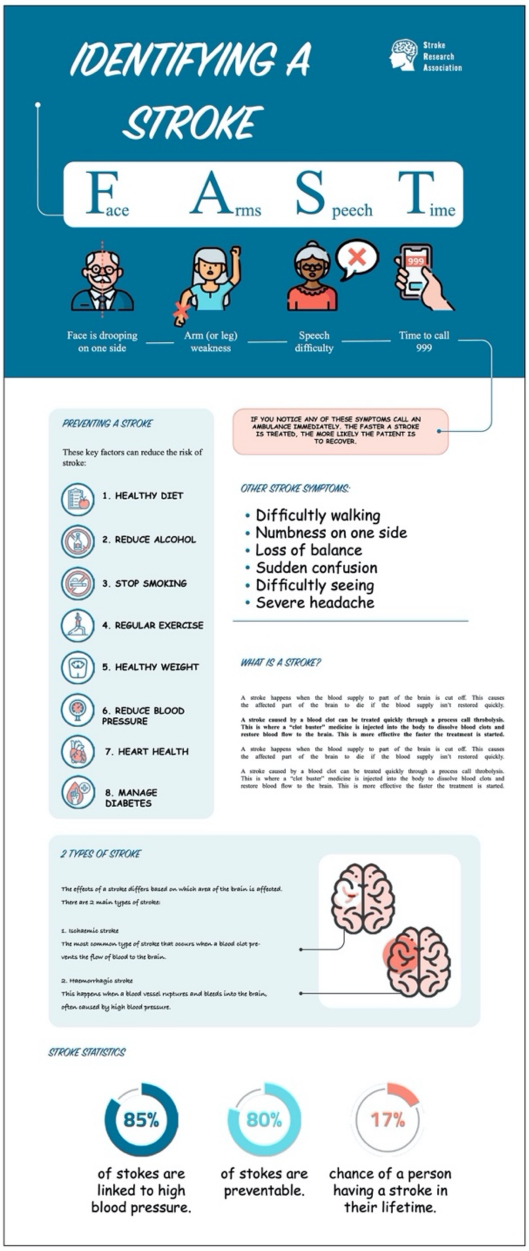


Figure 4.2 (cont.). The designs that were created and used within the motion graphics videos to display the infographic 'before' and 'after' applying the principles discussed in the video.

3. TYPE INFOGRAPHIC

Before



After

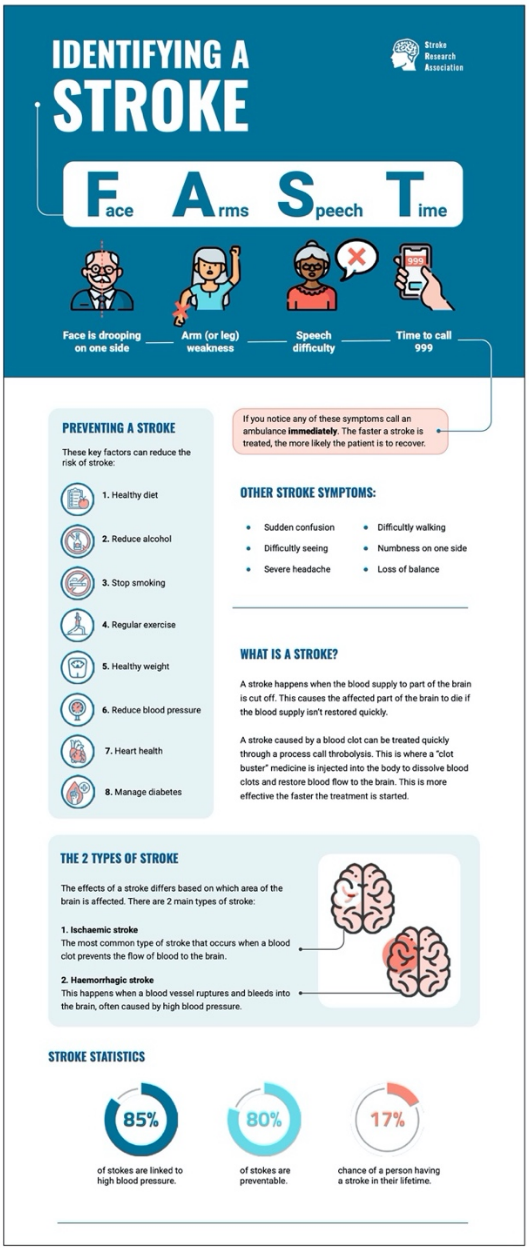
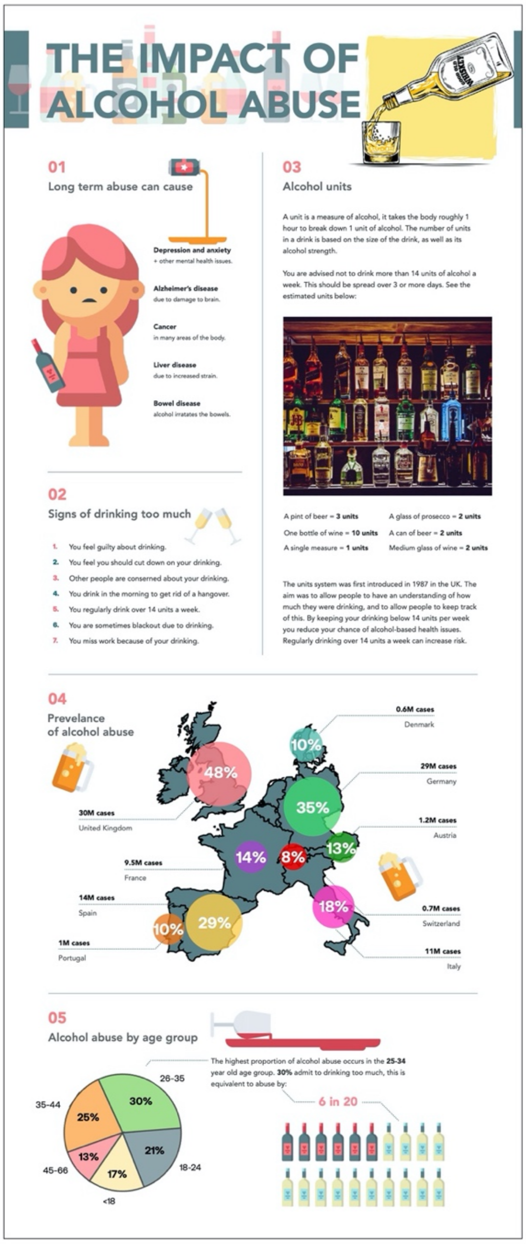


Figure 4.2 (cont.). The designs that were created and used within the motion graphics videos to display the infographic 'before' and 'after' applying the principles discussed in the video.

4. GRAPHICS INFOGRAPHIC

Before



After

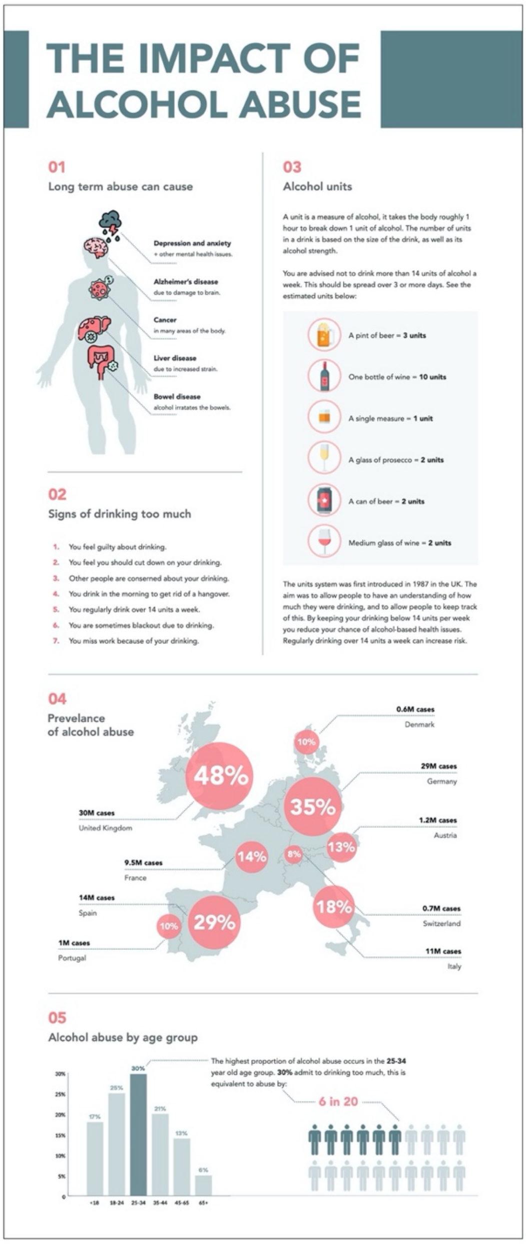


Figure 4.2 (cont.). The designs that were created and used within the motion graphics videos to display the infographic 'before' and 'after' applying the principles discussed in the video.

4.5.2. Usability testing stage 1

The first stage of usability testing was undertaken with only 1 video, as all the other videos would follow the exact same format just with differing content. The usability testing took part in 2 stages aiming to gather research from both the target audience of the videos (healthcare professionals) and information design specialists. By gathering feedback from both groups, it generated a user-centred approach that was informed by information design experts. A similar approach was undertaken by Lonsdale et al. (2020b) in the development of user centred patient information leaflets, who collected usability data using co-design workshops with medical experts as well the target user of the design. The aim was to involve all potential stakeholders in the design process (e.g. patients, doctors, nurses) (Lonsdale et al., 2020b). Although information designers were not the target audience of the design, their involvement in the usability process can help provide feedback on more specific design elements. There is also scope for the resource to be used by design students to assist their learning, or even as a refresher resource for more experienced infographic designers. Thus, feedback from both healthcare professionals and design experts here can provide valuable input.

Nielsen (2000) states usability testing need only take please with 5 participants as the majority of usability problems is identified in a group this small. Thus, both stages of usability testing were completed with 5 participants each. The participants were encouraged to 'use' the motion graphics resources. To replicate how the motion graphics would be used by a potential user, the participants were asked to watch the videos then asked to answer a series of questions. The answers to which were described in the videos, this was to ensure a level of learning had taken place.

This first stage of testing was undertaken with 5 healthcare professionals. They had an age range of 20-56 years old and included 2 dental students, 1 paediatric nurse, 1 physiotherapist and 1 research physiotherapist. The following questions were asked, aiming to identify any design problems and potential for improvement:

1. Do you feel the video would help you to use the layout principles if you were to create an infographic/poster?
   Please explain your answer:

2. How would you rate the length of the videos? (Likert 1-5)
3. How would you rate the pace of the videos? (Likert 1-5)
4. How would you rate the voiceover of the videos? (Likert 1-5)
5. How would you rate the background music in the videos? (Likert 1-5)
6. How would you rate the layout of the elements in the videos? (Likert 1-5)
7. How would you rate the colours used in the videos? (Likert 1-5)
8. How would you rate the graphics and images used in the videos? (Likert 1-5)
9. How would you rate the ‘example’ sections of the videos? (Likert 1-5)
10. How would you rate the 'before/after' sections of the video? (Likert 1-5)
11. How would you rate the transitions in the video? (Likert 1-5)
12. For any of the above ratings that were rated between 1-3, can you please explain why:
13. How would you rate the effectiveness of the video OVERALL?
14. Is there anything in the video you do NOT understand?
15. Do you have any suggestions to IMPROVE the video?

Generally, feedback was positive with 100% of the participants stating that the motion graphic would help them use the design principles when making their own infographics. The step-by-step format was thought to be easy to follow and the videos had the right amount of content to teach the principles. It was said the that the visual examples showing how to apply a principle were very useful. There were positive ratings for the following features: length of video, voiceover, layout, graphics, example section, before/after section, transitions. However, some participants found the pace of the videos to too fast, with one also finding the videos too long. One participant suggested making the before/after section clearer by having a visual indication of what infographic is the before and which is the after. There were some mixed opinions on the background music with one participant describing it as distracting.

Based on the feedback the following changes were made to the motion graphic video:

- Slowed down the pace of the video without greatly extending overall duration. This was achieved through slightly longer transitions to give longer break between sections, creating a break to separate chunks of information.

- Reduced the overall length of the videos by re-recording all the 'example' sections of the motion graphics to make sure they were shorter, but still covered the same amount of content at an appropriate pace.
- Added "Before" and "After" labels to the before and after section, as well as an animated arrow to clearly display which infographic was which.
- Add animation to the "Before" and "After" section to show what was changed when the design principle was applied.
- Found better quality and less distracting background music.
- Added more of the light blue highlight colour in the videos to make sure the colour palette of the videos more appealing.

Once these changes were implemented the remaining 3 videos were developed in accordance with the improved initial video; resulting in 4 motion graphics videos that covered all 20 design principles. This was taken to the second stage of usability testing.

4.5.3. Usability testing stage 2

The second stage of usability testing was undertaken with 5 information designers, all the participants had studied and were currently working or researching in the field of information design. The age range of the participants was 25-28 years old. The usability testing criteria that was user is stage 1 was repeated, with the same questions asked.

Again, the feedback for the videos was mostly positive. All the participants thought the videos would help non-designers to use infographic design principles. The step-by-step principle application with examples was thought to be an effective method of educating non-designers; one participant stated "I love the way to introduce principles by re-designing selected examples step by step". The motion graphics were said to be effectively designed and that all the information was easy to understand. There was some criticism of the audio quality, with 2 participants once again finding the background music distracting and too loud compared to the voiceover. One participant also found the voiceover quality to be lacking in sections. Another participant also thought it would be beneficial to add a summary section at the end to summarise the 5 principles in each video. The participants were also asked if they thought any additional teaching material would be beneficial to the target audience to help them understand the design principles. The majority of the information designers thought an additional pdf booklet would be beneficial to the target audience to allow the user to "have the design and the principles side by side".

Based on the feedback the following changes were made to the motion graphic video:

- Re-recorded some of the voiceovers to improve the audio quality.
- Found better quality and less distracting background music, reduce the volume of this so the voiceover is clearer.
- Improved the quality of some of the animated elements in the videos.
- Developed an additional resource that summarised the 20 infographic design principles. This was an online pdf resource that showed the infographics before and after applying the principles, showing where the principles were used
- Added an additional summary section at the end of each of the 4 videos that discussed the 5 principles that were covered and displayed the infographic before and after the utilisation of the principles.

The changes were made to the 4 videos, and they were uploaded to YouTube to allow them to be hosted online. The positive feedback from both stages of the usability design also suggested there were not any major design flaws in the motion graphic videos. Every participant from both stages of the usability testing made comment that the resource was clear and easy to understand. Based on this feedback, and after making the necessary changes, the resource appeared to be appropriate for its purpose. That is, to educate non-designers on how to use infographics principles when creating their own infographics.

4.5.4. Final education resource

Additional supporting material was developed in accordance with the feedback during the second stage of usability testing. The participants thought that the additional resource should be something that summarises the videos, but also something static that can be consulted easily during the design process. Most of the participants thought that an online PDF would be most appropriate. Consequently, a 5-page PDF was created that summarised the 20 infographic design principles from the videos. The first page re-introduced the principles, and then the 5 principles from each video had a dedicated page. On each of these pages the 5 principles from the category were listed alongside the infographic before and after applying the principles. Lines were also added to indicate where the principle had been applied on the designs, and to provide a clear reminder of how to use the principle effectively. The additional PDF can be viewed in Figure 4.3 (below).

The final motion graphic output can be accessed via the following links:

Layout: https://www.youtube.com/watch?v=llzXut1aFkg
Colour: https://www.youtube.com/watch?v=b4WR12iiVmA
Typography: https://www.youtube.com/watch?v=pnvPMZnKWFU
Graphics: https://www.youtube.com/watch?v=f7kQK8AeNd4

Screenshots of the videos can also be viewed on Figure 4.4 (below).

Page 1

Page 2

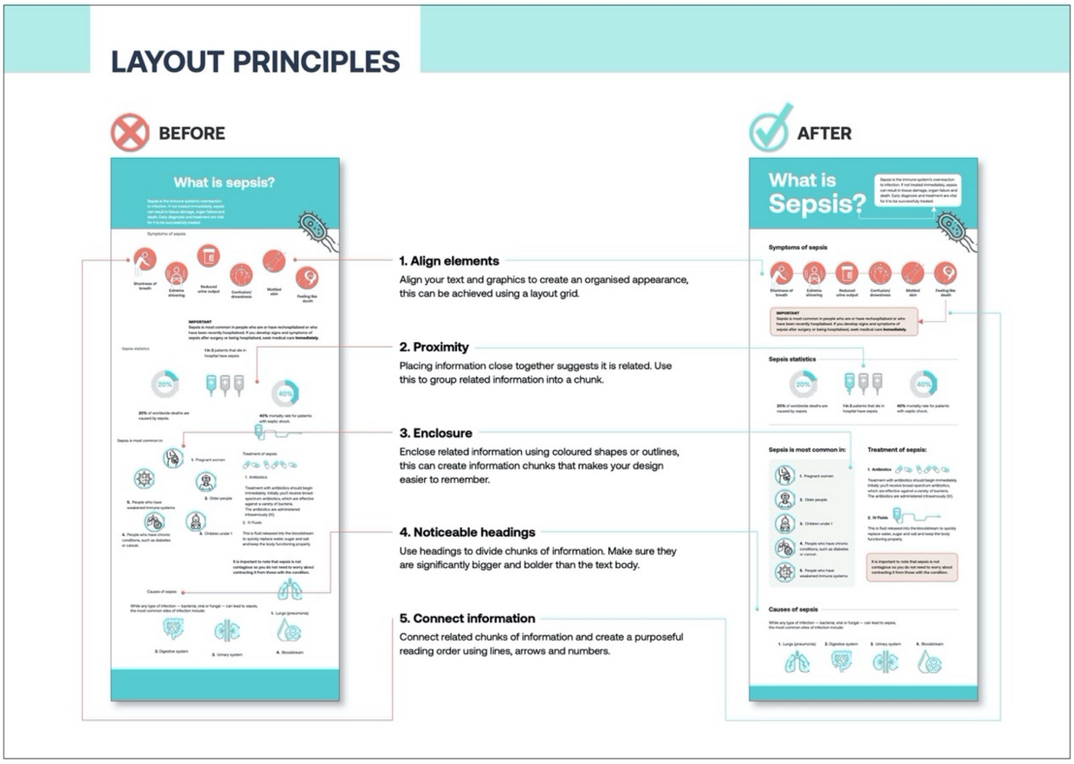
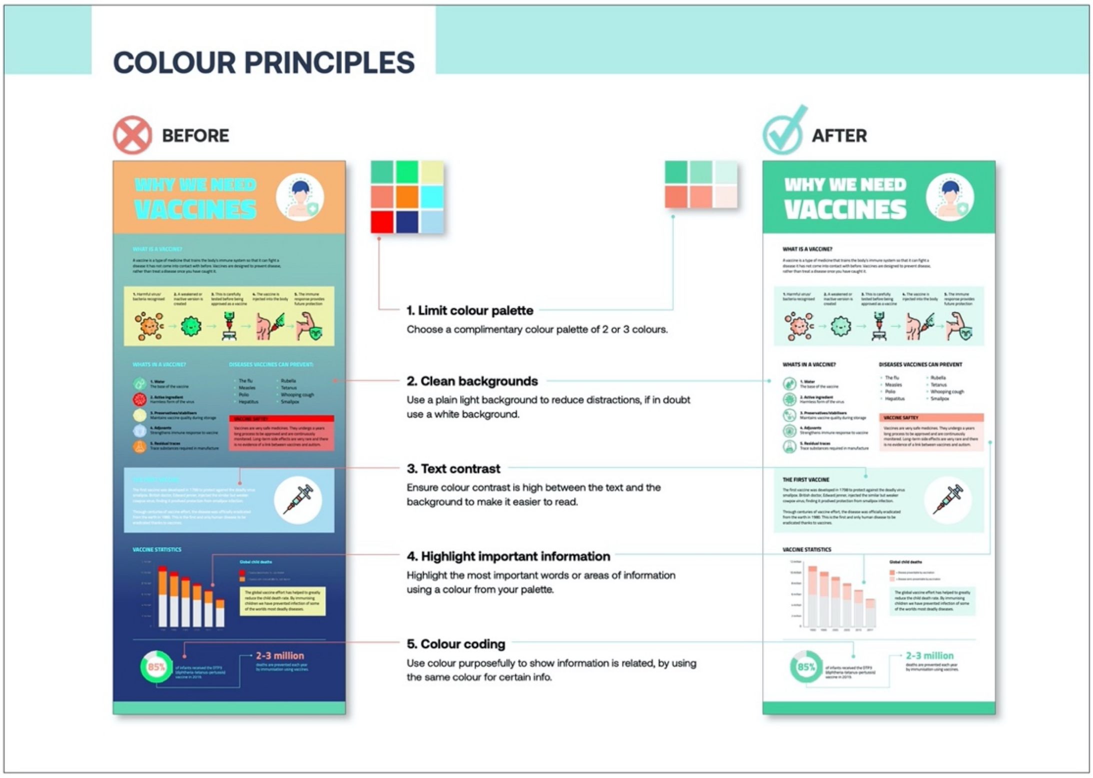


Figure 4.3. Additional PDF that was developed to summarise the 20 principles covered in the motion graphics videos.

Page 3



Page 4

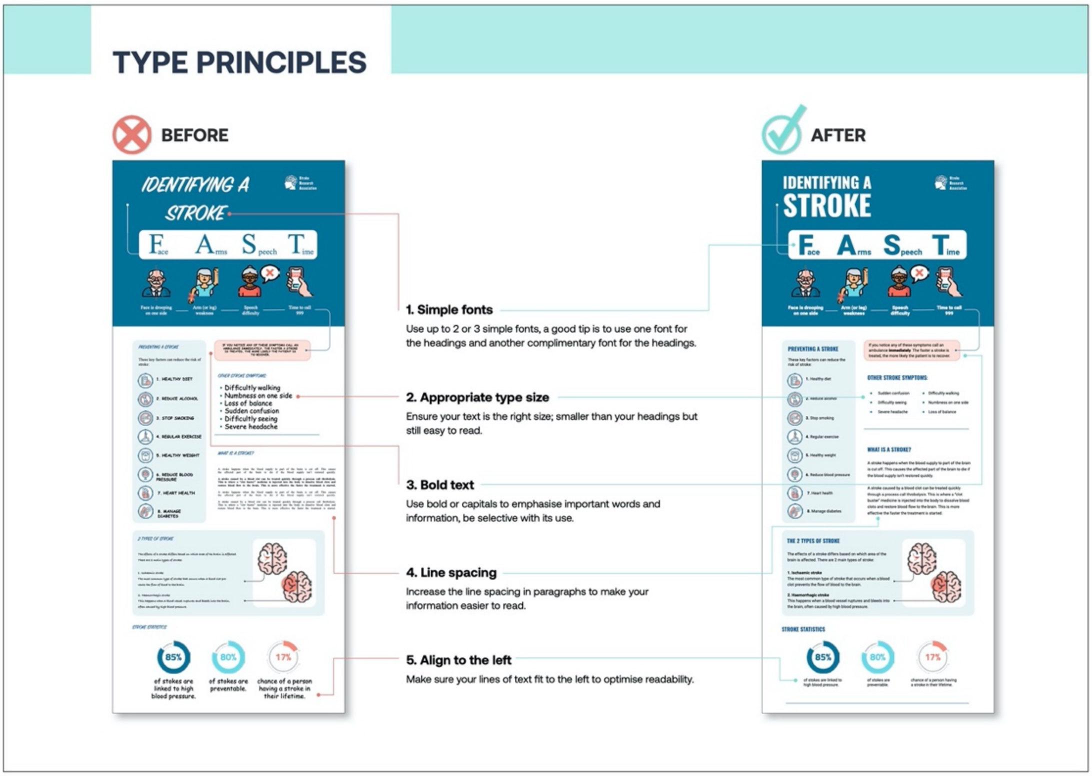


Figure 4.3 (cont.). Additional PDF that was developed to summarise the 20 principles covered in the motion graphics videos.

Page 5

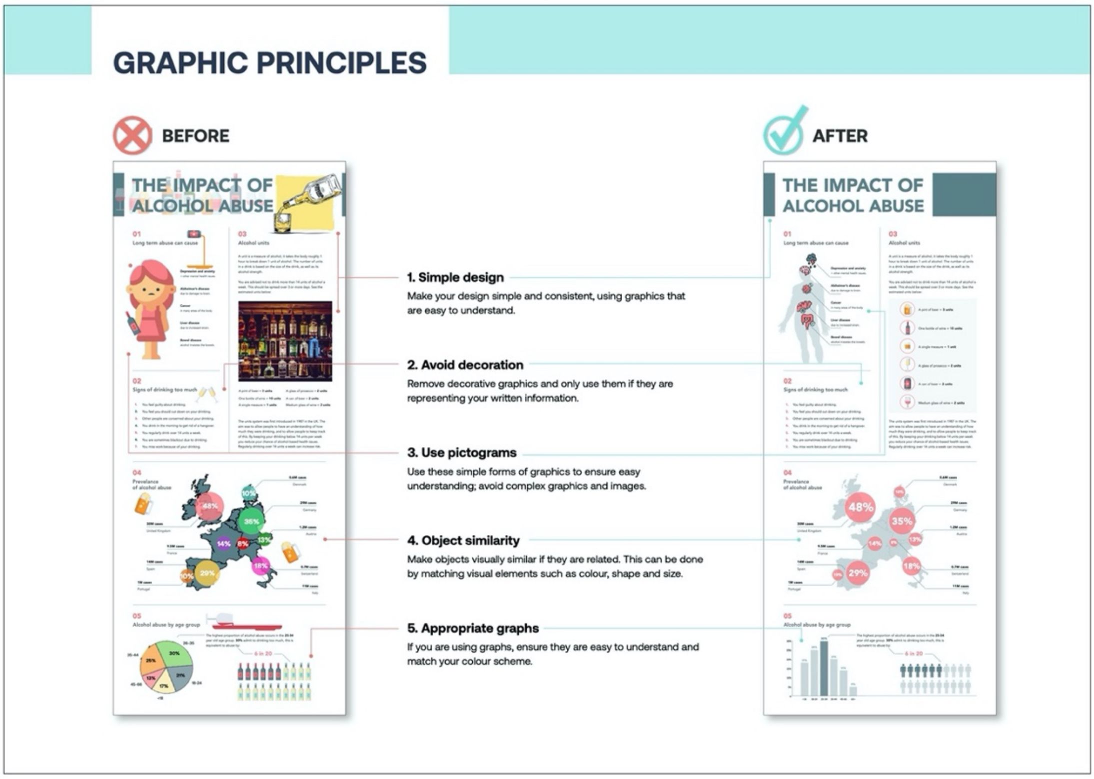


Figure 4.3 (cont.). Additional PDF that was developed to summarise the 20 principles covered in the motion graphics videos.

Figure 4.4. Screenshots of 1 of the 4 educational motion graphics videos; this displays the 'layout principles' video.

4.6. Chapter 4 summary

The aim of this chapter was to create a resource that educated the user on how to use the design principles established in chapter 2. The results of chapter 3 had shown that the application of design principles can improve the effectiveness of public health infographics. Consequently, this resource looked to find a way to allow a non-design audience to understand and apply these principles in the creation of their own infographics. First, however, a problem had to be addressed. It was acknowledged that the adherence to the 84 design principles defined in the project was unrealistic for the target audience of non-designers. The limited design experience exhibited by the prospective user of the resource meant they had to be as accessible and easy to understand as possible. Therefore, the principles had to be condensed to a more practicable number, leading to a 3-stage reduction method that aimed to retain the most and pragmatic design principles. In this first stage, a logic-based analysis was employed to remove principles that were too general, subjective, or impractical for a non-designer to adhere to, reducing from 84 to 66 principles. Next, a basic form of exploratory factor analysis was used to group principles with a common factor into a singular principle, reducing the number from 66 to 40. Finally, the analysis of existing 'good' infographics was used to help identify the most salient principles required to create an effective design. As well as a secondary analysis stage to combine further principles, resulting in the final reduction from 40 to 20 core principles. These principles were divided into 4 categories (layout, colour, typography, and graphics) with 5 in each.

The next stage of the research aimed to develop the education resource that would teach the target user how to apply these 20 core principles. The resource was designed to be both accessible and engaging, resulting in the choice of a motion graphic video series format. Consultation of the appropriate literature revealed this as an appropriate education method in an instructional context. An iterative user-centred design process was employed to ensure the motion graphics were optimised for the target audience, as was again influenced by the relevant literature. Motion graphic design principles from applicable research publications were also adhered to in the design process to make the videos effective in their purpose. Multiple stages of usability testing were employed to develop the motion graphics education resource, as well as the complimentary pdf that summarised the content in the videos. The final education resource output looks to successfully educate non-designers on how to apply the 20 design principles. The practicality of this resource is investigated in the next chapter, that experimentally compared the infographics that were created by healthcare professionals before and accessing using the motion graphic videos.

5. Chapter 5 – Education resource testing

5.1. Chapter 5 introduction

Following from the design development from chapter 4, the core aim of the chapter is to study the potential benefit of the education resource that was created. The chapter investigates if educating healthcare professionals on using infographic principles would result in this target audience designing more effective infographics. The research in this chapter was conducted remotely due to limitations posed by the COVID-19 pandemic. This education resource took the form of motion graphic videos developed in the previous chapter that described how to use 20 infographic design principles. A novel design research approach was employed to address these aims through a remote research method. Consequently, a heuristic generative design approach was employed, using a combination of 2 existing design methodologies. The first is generative research which is a participatory exercise asking participants to generate a design concept (Martin and Hanington, 2012); however, this was done individually not as a co-design exercise with the researcher. The second is heuristic evaluation with involves the assessment of a design based on agreed-upon practises (Martin and Hanington, 2012), in this case the application of infographic design principles.

The 9 healthcare professionals that took part in the heuristic generative design stage created 2 infographics each. The resulting 18 infographics were first evaluated by the researcher to determine which of the 20 infographic principles had been applied by the participants. It was hypothesised that the infographics created after accessing the resource would apply more principles. An improvement was observed with every participant, an average increase of 171% more principles were applied. The 3 most improved pairs of infographics were taken to the final stage of testing to determine, through experimental testing, if a meaningful performance improvement was made with participants using the infographics designed after using the education resources. Again, it was hypothesised that these 'after' infographics would perform better. A remote online study was completed with 60 participants divided equally into 2 groups. The findings supported this hypothesis with significantly better information location time, information recall accuracy, recall time, and more positive user opinion with participants using the infographics designed after accessing the education resource. Based on these research findings, it was concluded that infographic principle education using motion graphics is an effective tool to allow non-designers to improve their infographic design outputs.

Within this chapter the 'effectiveness' of the infographics is frequently discussed and compared. Effectiveness in this case is determined by the performance measures of the experimental testing which included: information location speed, information memorability, and user opinion. The chapter is divided into 2 stages. The first generating infographics using healthcare professionals participants before and after they accessed the education resource, the second experimentally compares the designs from the 2 groups.

5.2. Stage 1 – Infographic generation

5.2.1. Infographic generation summary

The aim of this chapter was to investigate the effect that educating non-designers on using infographic design principles would have on the design of public health infographics. To achieve this a 2-stage study was implemented. First, the participants were given a set of information and graphs and given 90 minutes to create an infographic. After a break of a week the process was repeated asking the participants to design a second infographic using the same information. The difference was that the participants were required to watch a series of 4 education motion graphic videos before this second design stage.

These videos covered 20 research-based infographic design principles and how to apply them. The 4 videos were divided into the following categories: layout, colour, graphics, and typography. The participants were required to watch all 4 videos in the break between the first and second experiment, and again just before the second experiment began. They were also given access to a pdf that summarised these 20 principles for easy reference whilst they were designing during the second experiment.

The overall aim was to investigate the effect that the education of applying design principles has on health-related infographic design. It was hypothesised that the infographics designed in the second stage would be of improved effectiveness, due to the participants learning from the videos and effectively using more infographic design principles. Previous research from this project has shown that the effective application of design principles results in improved infographics.

5.2.2. Participants

To be eligible for the study the participants had to be over 18 years of age and to be native or fluent in the English language and to not have colour blindness. They were also required to work or be studying in a healthcare profession. Eligible participants included: doctors, nurses, dentists, physiotherapists, and phycologists. The participants were required to have a moderate level of computer literacy to take part in the research; with experience using common design software such as Microsoft PowerPoint or Google Slides. The participants were contacted directly by email to enquire about their eligibility and willingness to participate in the research.

9 British participants were recruited for the study. Of the participants, 7 were doctors, 1 a nurse, and 1 a research physiotherapist; all based in the UK and working for the NHS. The age of the participants ranged from 24-57 years old.

Before the study began the participants were provided with an information sheet, then asked to submit a consent form and a questionnaire to provide personal details (e.g., age, profession). They were also asked if they had been required to create an infographic for work or the course they were studying. All 9 of the participants stated they had been required to create an infographic for their work or study. The participants were asked to describe what infographics they had to design and where they were displayed. The content of these infographics included:

- Medical school infographic posters
- Medical study research presentation
- Clinical Audit results presentation

- Patient information posters
- Medical course group project presentation

These were displayed in the following scenarios:

- GP practises
- University medical schools
- Group medical teaching sessions
- Medicine research conference (e.g., British Transplant Society conference, presented at both national and regional level)
- Hospitals (displayed within the trust)

This provides some evidence that healthcare professionals are being required to design infographics, and these are being displayed in public settings such as hospitals, GP practises and national conferences. Given the lack of design experience in all the participants, this may present some explanation for the lower quality infographics sometimes published by the NHS and other healthcare bodies (as displayed in the thesis introduction). It appears that some publicly visible health infographics are being produced by healthcare professionals with limited design experience.

The aim of the education resource that was developed is to allow non-designers, such as healthcare professionals, to create infographics that are attractive, and easy to use and understand. The experiment was constructed to emulate the use of the resource in a practical setting.

5.2.3. Experimental design

The experiment was split into 2 stages. Both stages requiring the participant to design an infographic using supplied information and graphs, as well as images from the search engine Google. They were required to include all the written information on the pdf supplied to them on their infographic. The context of the information was heart attack awareness. The information was collected online from NHS (NHS, 2021b), Mayo Clinic (MayoClinic, 2021) and the British Heart Foundation (BHF, 2021) websites.

All participants completed the study on their own to prevent them from influencing each other's design development. The participants also used all their own personal laptops for the study, to emulate a realistic design process as if they were asked to create an infographic through work or education courses. All the laptops used in the study had 13-inch screens. The design was completed using Google Drawings. This is a free to use software that is available to anyone with a Google account. This software was chosen as it is both free to use and online software so every participant would be using the most up to date version. The software is also very easy to use; functioning similarly to familiar software such as Microsoft PowerPoint, but with streamlined features specifically for the design of diagrams and infographics. None of the participants had any difficultly using the software.

The researcher was present throughout the study to verbally explain the requirements of the research and allow the participants to ask any questions before the experiment began. The researcher was also present to answer any questions about how to use specific features of the Google Drawings software (e.g., how to change background colour), as this was software some had not used before. Despite some participants not using Google Drawings before, the accessible and familiar design of the software meant they had minimal difficulty in the design process. Very few questions were asked in how to use or locate features of the software and some participants expressed verbally how easy it was to use.

The size of the infographic was determined by multiple factors. The first being by consulting a large body of health-related collected by the researcher throughout the PhD project to determine an appropriate size ratio. Most infographics appeared in a width:length ratio that was longer than an A4 ratio (1:1.41) and a shorter than 1:3. The second determining factor was the amount of information the participants were required to include on their infographic. Initially the researcher designed an infographic using the information to find what size ratio would be appropriate to fit the text alongside graphs and images collected from the internet. The same ratio was provided during a pilot study and the ratio was thought to be appropriate by the participant. This resulted in a width:length ratio of 1:2.2, meaning the infographics were 1000 x 2200 pixels in size. The participants were required to design all their infographics within these dimensions.

In both experiment 1 and 2 the participants were provided with an infographic design template, the information to be included on the infographic and a selection of graphs they were required to use; all provided by email. The infographic template was a completely blank 1000 x 2200-pixel canvas on Google Drawings.

The infographic information was given as a pdf. The first page contained all the written information the participants needed to include in their design. The participants were told that the text in blue was not to be included in the infographic, it was present to provide organisation or context to the information (Appendix 2). The information also included 3 sets of statistics. The participant was required to select a graph for each of these sets of statistics, there were 6 variations for graph 1 and 5 variations for graph 2 and 3 (Appendix 2). These graphs were of varying design quality. Once the graph was chosen the participant was required to choose a colour variation from 8 different colours including: dark blue, light blue, red, orange, yellow, green, pink, and purple (Appendix 3). The participants were also informed that if they required a specific colour on their graphs (e.g., to closely match a colour scheme) this could be implemented by the researcher after they have completed their design. This was to make the infographics reflective of common health infographics which frequently include graphs.

It may be suggested that the basic Google Draw software may be a factor that affects the quality of the design output. However, this free and simple software still allows for the creation of high-quality infographics. The researcher created the infographic shown in Figure 5.1 using the Google Draw software and the information used by the participants to create their own infographics. All 20 of the design principles defined in chapter 4 were adhered to in the design. This was not shown to the participants at any stage of the research to prevent any influence over their own design process.

Example infographic

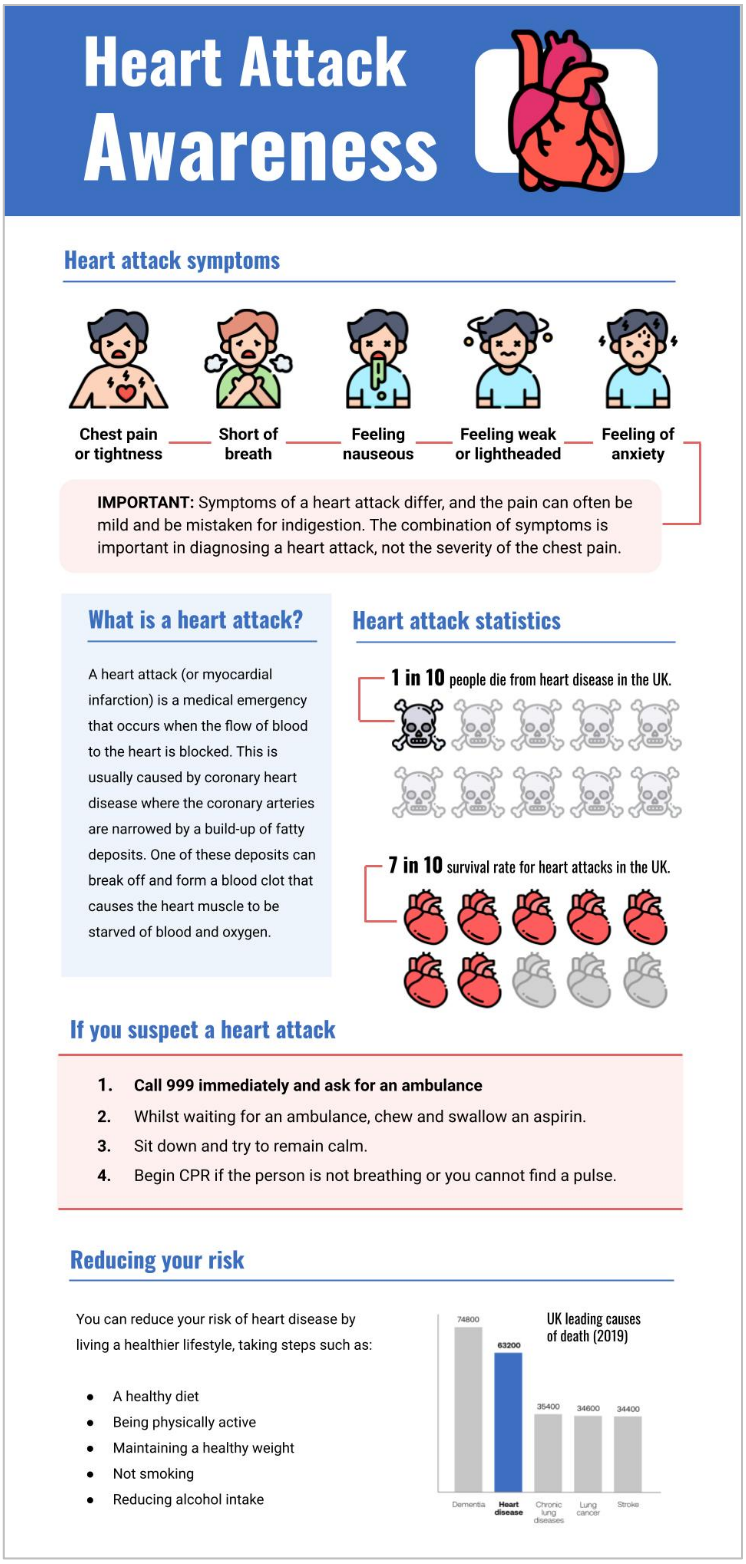


Figure 5.1. An infographic designed by the researcher that applies the 20 design principles using the heart attack information the participants were given in the heuristic generative design stage

5.2.4. Experiment 1

Before the first experiment began, the participants were emailed an information sheet to read. They were also asked to complete a consent form and personal details questionnaire. The personal details questionnaire asked the participants to list their age, gender, profession, and nationality; as well as details of infographics they have been asked to design in the past for work or whilst studying for their healthcare degree.

Before the start of the experiment the participants were provided with a definition of an infographic, then asked to search for the term 'infographic' on Google Images so they had a clear understanding of what they were being asked to design. They were then instructed to close Google Images. During the experiment they were also asked to refrain from searching for and copying other infographic designs from the internet. The instructions of the experiment were explained to the participants verbally and were allowed to ask any questions they had about the research before the study started. They were also informed that they could ask questions at any time regarding how to use the software features.

Once the experiment was completed the participants were asked to save and exit the software. They were then informed that they would be required to watch the 4 motion graphics videos in the time between the first and second experiment. Links to these videos were sent via email after the first experiment was completed to be watched in their own time.

5.2.5. Experiment 2

Before the second experiment began, the participants were emailed to ask them to create a free account on the website 'www.flaticon.com'. Access to this pictogram database is useful in applying some of the graphic principles described in the videos, though the participants were still allowed to gather images from anywhere they wanted on the internet. They were also asked to download the supplementary pdf file that summarised the 20 principles described in the videos.

To begin the second experiment, the participants were asked to watch the 4 motion graphics videos again. They were also required to view the principle summary pdf and have it open somewhere accessible on their laptops during the second experiment, being told they could refer back to the pdf or videos at any time during the design. Again, the participants were asked to design an infographic using the same process as in experiment 1. They were provided with the same information, graphs and template and given a 90-minute time cap.

After the second experiment was completed, the participants were emailed an opinion questionnaire. The aim of the questionnaire was to gather the user's opinion on both the motion graphics videos and supplementary pdf that they used to assist in the design of their infographics. A combination of Likert scales and open questions were employed to explore how helpful these education tools were to the participants. This was conducted on Google Forms and took between 5-10 minutes to complete.

5.2.6. Design outcomes

The infographic development stage resulted in the design of 18 infographics by 9 healthcare professionals. Each participant created 2 infographics; the first with no input, and the second after watching a series of instructional motion graphics aiming to educate them on how to create effective infographics through the application of design principles. The infographics can be viewed below on Figure 5.2.

Of these 9 pairs of infographics, 3 pairs were selected for later experimental testing. The purpose of the testing was to investigate if the infographics designed after the participants watched the videos were more improved than those designed with no educational input. ‘Improvement’ would be measured by performance data including information location speed and recall accuracy, as well as user opinion data; the same measurement parameters that were used in the study in chapter 3. Significant improvement would suggest the educational motion graphics made an impactful benefit to the design of the public health infographics.

Throughout this chapter, ‘G1’ will refer to the infographics designed in the first group; those that were designed by the healthcare professionals with no other input. ‘G2’ will refer to the infographics designed in the second stage; those that were created by the same participants after they had engaged with the education resource.

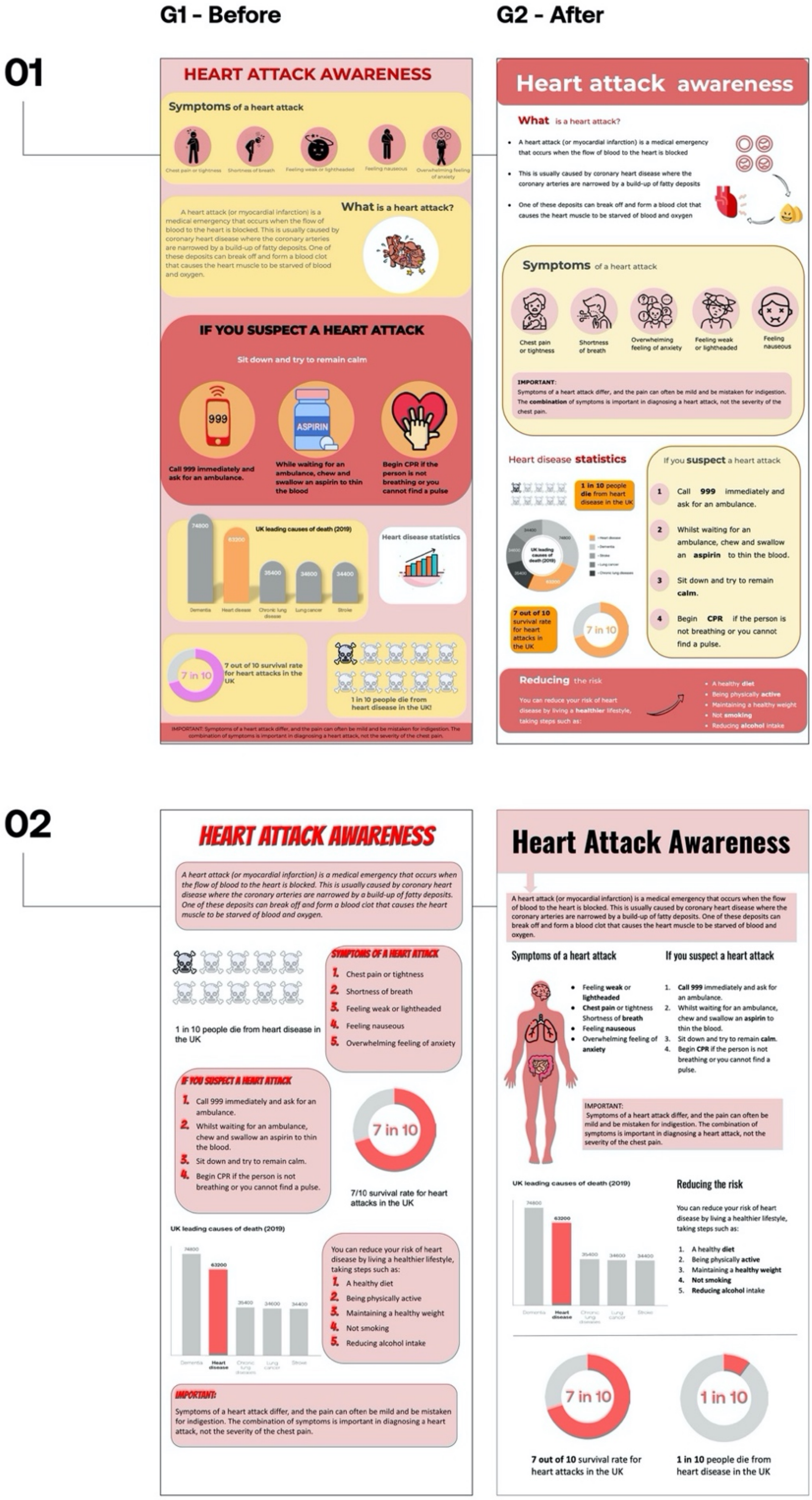


Figure 5.2 The infographics developed by healthcare professionals before (G1) and after (G2) accessing the education resource on implementing infographic design principles. The 3 infographics taken to the later testing stage are highlighted in blue.

Figure 5.2 (cont.). The infographics developed by healthcare professionals before (G1) and after (G2) accessing the education resource on implementing infographic design principles. The 3 infographics taken to the later testing stage are highlighted in blue.

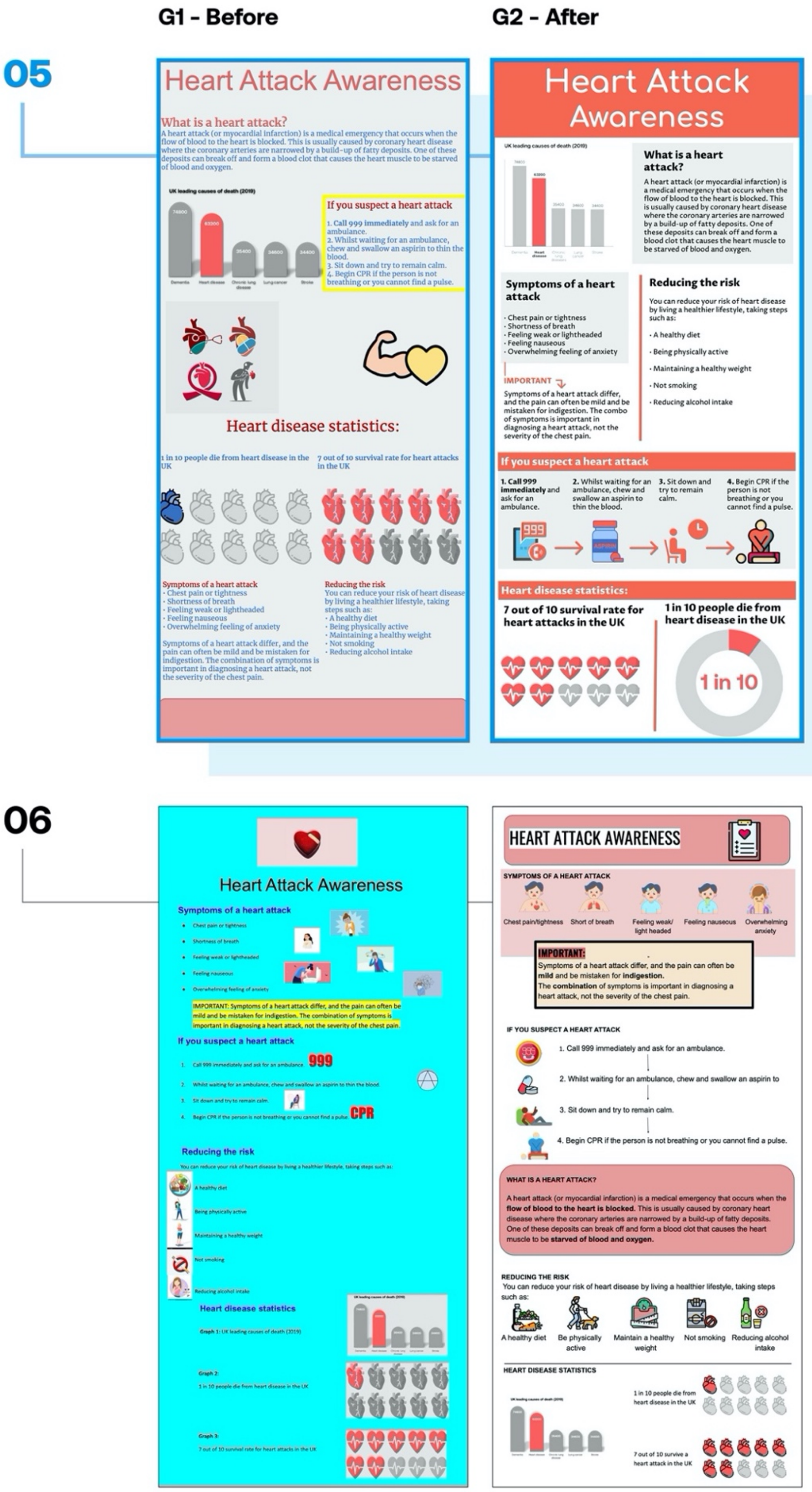


Figure 5.2 (cont.). The infographics developed by healthcare professionals before (G1) and after (G2) accessing the education resource on implementing infographic design principles. The 3 infographics taken to the later testing stage are highlighted in blue.

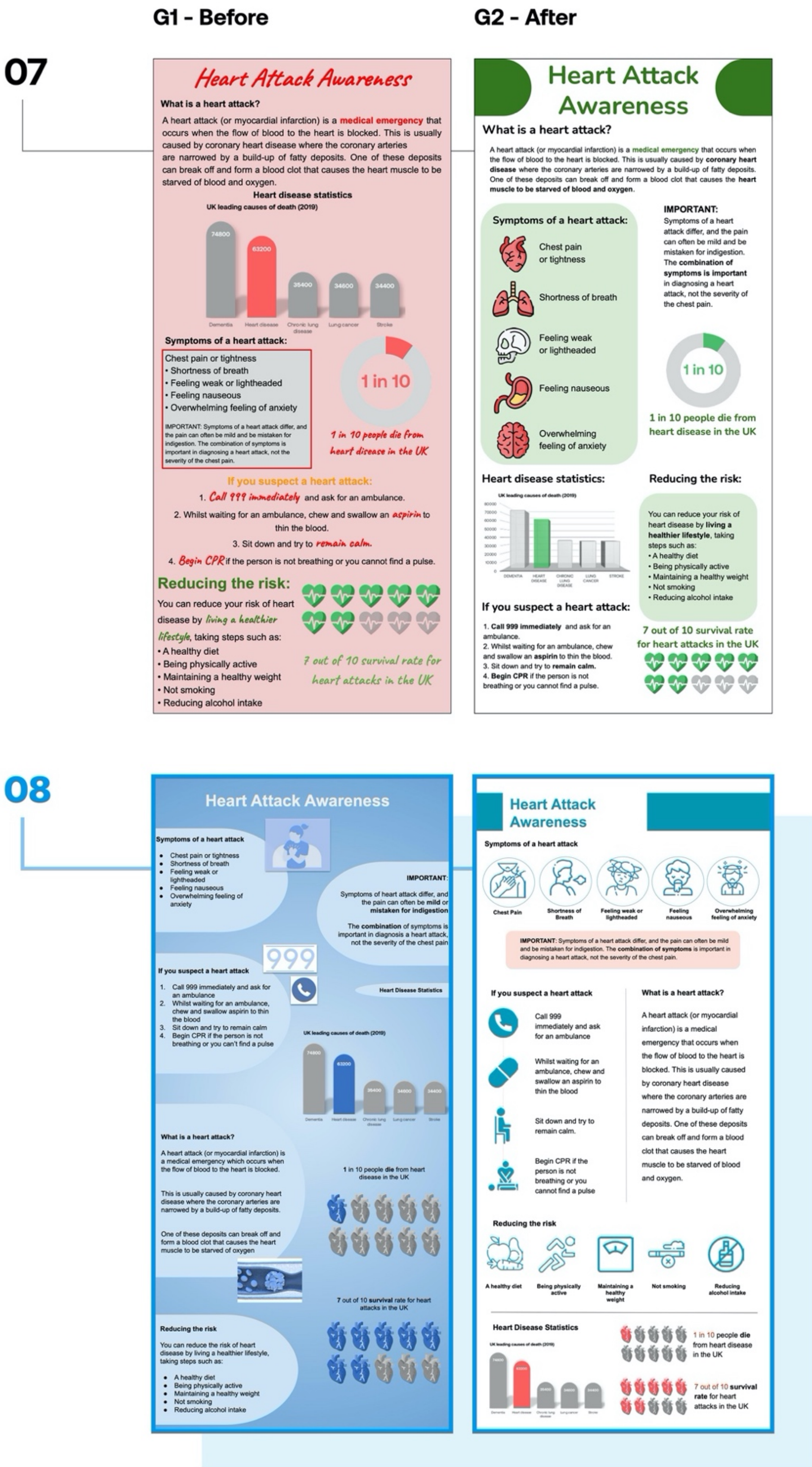


Figure 5.2 (cont.). The infographics developed by healthcare professionals before (G1) and after (G2) accessing the education resource on implementing infographic design principles. The 3 infographics taken to the later testing stage are highlighted in blue.

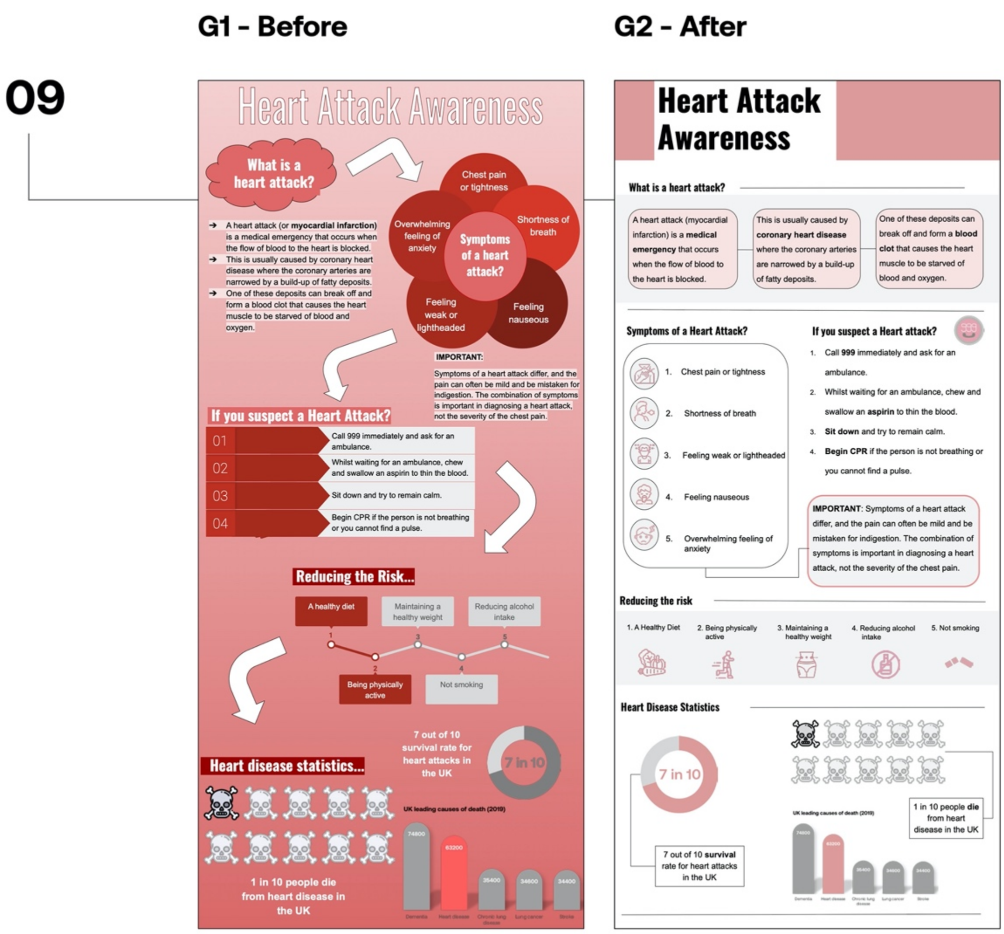


Figure 5.2 (cont.). The infographics developed by healthcare professionals before (G1) and after (G2) accessing the education resource on implementing infographic design principles. The 3 infographics taken to the later testing stage are highlighted in blue.

5.2.7. Opinion questionnaire results

After completing the two design stages, the participants also undertook an opinion questionnaire to gather their opinion on the motion graph videos and additional pdf they used to learn about infographic principles. The participants were asked to answer likert scale and open questions regarding these education resources. The results of the Likert scale questions can be viewed in Figure 5.3 below.

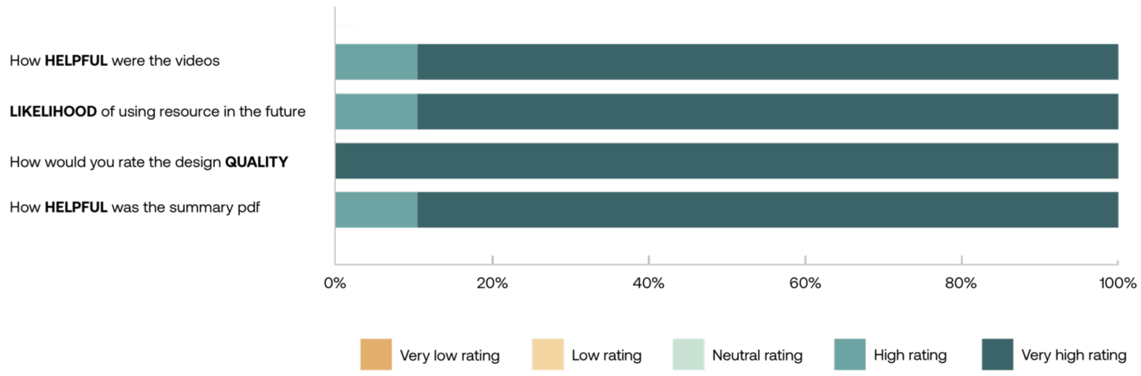


Figure 5.3 Graph displaying the Likert scale results from the questionnaire assessing user opinion on the education resource.

All the participants thought that the videos helped them to design a better infographic in the second stage. When asked how helpful/unhelpful they found the videos in teaching them how to use design principles, 8/9 rated them 'very helpful' and 1/9 rated them 'helpful'. The participants thought that the videos were clear, engaging and easy to understand with an appropriate amount of concise content. They enjoyed the structured approach of the principles covering quality content in "manageable chunks". The participants were able to recognise faults in their first designs that were highlighted in the videos, and were able to alter this using the principles that were "simple and easy to keep in mind" and "dramatically improved my knowledge of how to make a good infographic". Some notable quotes by the participants in this section were as follows:

1. "Although I was happy with my first infographic, I could see areas from the poorly designed poster examples in the video that related to my own. It was useful to try and apply the design techniques to improve my infographic."

2. "Seeing the concepts applied to create better infographics was very interesting. I could have told someone that the improved infographics were better, but I would have no idea how to qualify such a stance. I also wouldn't have known how to replicate such techniques without watching them in an applied way."

3. “I had no prior knowledge of what made a good infographic and the best ways to convey information. I think that the impact of my learning having watched the videos is evident in the difference between my two infographics.”

When asked how likely they would be to use education resources like this if asked to design an infographic in the future, 8/9 rated ‘very likely’ and 1/9 rated ‘likely’. They considered the resources something they would refer to again to refresh what they learned. Some participants also stated that they are offered no real teaching on information presentation during medical training, despite it being something they often find themselves doing; concluding that they would use the resources provided to design posters in the future. The participants also stated they would use it to create infographics for: medical audit results, teaching presentations, and research posters. The videos were considered a good introduction to design and a “cheat sheet” on how to make a good infographic. Some notable quotes by the participants in this section were as follows:

1. “If they are still available the next opportunity i get to make an infographic will involve a quick return to these videos to refresh my skills. It would make a huge amount of sense as I saw what an improvement they made while i was making the second infographic.”

2. “We don’t get offered any real teaching on presenting information in a medical career, yet it is something we find ourselves doing often for research/audit/educational purposes. These resources will be useful to look back on when trying to design posters/visual representations of research.”

3. “Very useful to refer back and I appreciate they are split into separate videos so can find what you want to remind yourself on more easily.”

When asked to rate the quality of the videos, 9/9 gave them the highest rating of ‘very high quality’. They considered them professional and easy to watch. They thought the voiceover was clear, and the graphics well designed with an appropriate amount of information. The participants also found the videos concise with a good pace, and were pitched at the right level. One participant did note that they found the videos too quick in parts, but still considered them well designed.

The participants were asked what they would improve about the videos. 6 of the 9 participants thought there was nothing they would improve in the videos. Some suggestions for improvement involved: the inclusion of a summary video to summarise the 4 videos, more time used to introduce the principles, and an interactive section that asks the user to identify areas to improve on an infographic.

When asked how helpful/unhelpful they found the additional pdf, 8/9 rated it as 'very helpful' and 1/9 as 'helpful'. The participants again responded very positively to the additional PDF that was used to summarise the principles covered in the videos. They found it concise and useful to refer back to during the design of their second infographic, rather than having to filter back through the videos.

Overall, the feedback on the education resources was overwhelmingly positive. All 9 of the participants provided positive feedback on the motion graphic videos, found them appropriately designed, and helpful in teaching them how to use design principles when creating infographics. The supplementary pdf resource appeared to be a justified addition to summarise the principles. The feedback suggests that the education resources were pitched at the correct level and work in a practical setting, achieving their purpose of an accessible learning tool for healthcare professionals with no design experience. This, alongside the design principle analysis, suggests that the education resource was successful in creating infographic outputs that better implemented design principles. The next stage of the research looks to statistically determine if there are improvements in performance for participants using the G2 infographics, compared to those using the G1 infographics.

5.2.8. Design principle analysis

To select which 3 pairs of infographics would be used in the experiment all 9 pairs were analysed by the researcher to determine how many principles were applied in in the design of the infographics. It was hypothesised that more principles would be applied on the infographics that were designed after the motion graphic education process. The researcher carefully considered each 20 infographics, one principle at a time, to determine if the principle had been used. The results found that on average, 7.7/20 principles were used in the G1 – before infographics. An average of 17.2/20 principles were used in the G2 – after infographics. This is an average improvement of 9.5 principles, or 170.6%, between the G1 and G2 infographics. Every participant showed an improvement with a range of 3-14 principle improvement within the 10 participants. The 3 infographics that were selected showed the most improvement with an increase of 12 (infographic 3), 14 (infographic 5) and 12 principles (infographic 8) between their designs from G1 and G2. These infographics can be viewed in Figure 5.2 and are highlighted in blue. The results of the analysis can be view below in Figure 5.4.

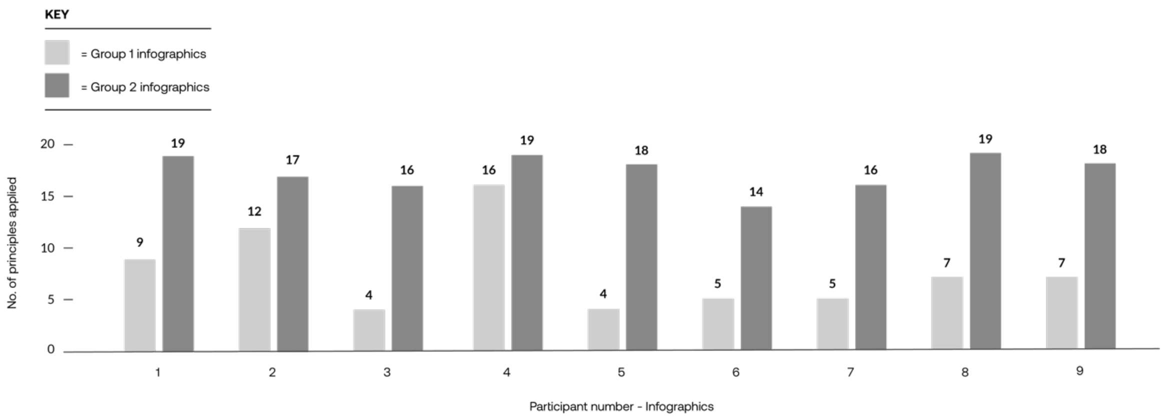


Figure 5.4. Graph comparing the number of design principles applied before (group 1) and after (group 2) using the education resource.

The opinion of a secondary information design expert was utilised to confirm the choices were appropriate. It is acknowledged that this analysis was a subjective process, as the application of a principle was determined by the researcher's informed opinion, with the opinion of an additional information design expert. However, this is not being presented as evidence that the G2 designs were more effective. Instead, it was used to inform the selection process of the infographics, with the aim to test the designs that appear to have made the most potential improvement. If all 9 pairs designs were used in the experimental testing, each design would only be used by 3 participants. By limiting it to the 3 most potentially improved pairs, it allows to test for both the highest potential benefit of the education process, as well as statistic comparison between the designs to examine if specific infographics within G1 or G2 were more effective.

The design principle analysis, alongside the opinion questionnaire results, suggests that the education resource was successful in creating infographic outputs that better implemented design principles. This, however, is not based on any statistically proven findings. The next stage of the research looked to address this by determining if the infographics from G2 are meaningfully improved compared to G1. Comparative data was later collected analysing the information location speed, memorability accuracy and user opinion of the 3 infographics selected from both G1 and G2.

5.3. Stage 2 – Infographic output testing

INTRODUCTION

5.3.1. Study Introduction

Infographics have been acknowledged as an effective tool in public health communication (Scott et al., 2016). They have been recognised as a means to make information both more accessible, easier to understand, and easier to remember when compared to written information (Lonsdale et al., 2019). This engaging method of information communication have been shown to improve the understanding of medical literature (Huang et al., 2018a), and significantly increase social media attention of research articles (Kunze et al., 2021). Their effectiveness in the field of public health have been recognised (Egan et al., 2021), and evidence has been found to suggest they reduce the cognitive effort required to understand complex health information compared to a written format (Martin et al., 2019).
Recent research has also found support for the use infographics to communicate COVID-19 information, with infographics being used to address COVID-19 vaccine misinformation and hesitancy (Rotolo et al., 2021). The importance of infographics has become clear during the pandemic with many recent publications focussing on this upcoming field. Hamaguchi et al. (2020) exemplified infographics as a means of effective

public health communication design, stating they can answer the need for the dissemination of accurate, useful information in a simple visual format. They argue that social media can be an influential tool in public education; the COVID-19 infographic they developed for their research reached over a claimed 120,000 people. The authors discuss the global enthusiasm for infographics, claiming they can be shared easily on social media to promote rapid transmission of important information. The conclude by emphasising the power of visual communication as a valuable tool to address health literacy disparities, and the promotion of public health messages. Further support for the use of infographics in COVID-19 information distribution come from a publication by (Chan et al. (2020)). Similarly, they created and shared an infographic for medical professionals on the subject of COVID-19 airway management. Finding it was widely shared across multiple countries and also concluding that social media infographics are an effective means to rapidly distribute key information. Though they warn that the information displayed on infographics should be critically reviewed before sharing on social media to avoid the dissemination of misinformation.

Infographics have also found to be useful in practical settings, looking to positively influence public behaviour related to COVID-19. Crutcher and Seidler (2021) discovered that the dissemination of COVID-19 vaccine infographics to first time vaccine recipients resulted in higher second dose uptake. A study by Egan et al. (2021) also looked at the effect of using public health infographics to educate the general public on the willingness and recall of face mask usage. They recorded that 3 of the 4 infographics they tested resulted in significantly higher average information recall scores compared to a control group that were shown no stimuli. Notably, no significant improvement in recall was observed for participants using written information from the UKGOV website; suggesting an infographic format is more effective in educating the public on COVID-19 information than just a text-based format. Willingness to wear a mask was high among all conditions. Research published by Lunn et al. (2021) found supporting evidence when exploring the use of infographics to educate the public on COVID-19 self-isolation information. Significantly better information comprehension and recall was recorded in participants using infographics, compared to a control group that viewed the same information in a written format. These studies indicate that infographics can be a powerful tool in public education and can influence positive behavioural changes.

The quality of currently available infographics can be variable, as can be observed by the published NHS infographics displayed in the introductory chapter. An issue may be that public health infographics are designed by healthcare professionals with limited design experience. As shown by the interview data from the first stage of this chapter, healthcare professionals are required to create infographics through for their study and workplace and are displayed publicly in hospitals and educational settings. This may be problematic, particularly in the field of public health, where poor quality infographics may result in lower user perception and information location efficiency (measured by information location speed and number of fixations) (Baxter et al., 2021).

Kemp et al. (2021) acknowledge that research in health-related infographics typically compare an infographic group with a control group, with limited guidance on how to design infographics to improve their effectiveness. The research here looks to directly address this problem, by determining if design principle application is an effective strategy to improve the design of infographics created by non-designers. As acknowledged in chapter 2, design principle application has been recognised as a means to produce effective infographics (e.g. Stones and Gent, 2015a; Lonsdale and Lonsdale, 2019; Baxter et al., 2021). Hernandez-Sanchez et al. (2021) recently published a set of guidelines specific to medical infographics, aiming to make them more effective. In their publication they recognise the effectiveness of infographics to communicate key medical information, but stress the importance of the design process and suggest a series of 12 research-based principles to create a effective design. Consequently, the use of design principles in the creation of public health infographics has been proposed as a potential method of producing high quality designs.

The use of infographic design principles as a solution, however, assumes the designer is experienced in the practice of their application. Given that infographics are sometimes designed by healthcare professionals with limited design experience, it would unrealistically require this demographic to be able to successful apply often complex design principles. Chapter 4 of this research addressed this problem through the development of motion graphic education videos, accessibly displaying how to use 20 core infographic principles when designing. As discussed at the beginning of this chapter, 9 healthcare professionals created heart attack infographics. Then in a second stage, after accessing this education resource, they aimed to create infographics that applied the principles they had learned. In this study, 3 of these pairs of infographics are experimentally compared to determine if the education resource resulted in a meaningful improvement in the effectiveness of the infographics.

5.3.2. Introduction - Limitation of existing research

A limitation presented in existing public health infographic literature lies in the common acknowledgement of the usefulness of infographics, but limited awareness on how an effective infographic can be designed. As previously acknowledged by Kemp et al. (2021). The designs tested in high quality experimental studies frequently utilise infographics that could be considerably improved. The publication by Stonbraker et al. (2019) is an example of this, where the infographics that were tested have the potential for improvement. They conducted a study looking to develop user-centred infographics for the communication of HIV information to patients. They utilised a participatory design approach, involving the end user of the infographics in the design stage to improve and tailor the final output. This resulted in the generation of 15 infographics, viewed as both clinically meaningful and culturally appropriate by the target audience. However, the infographic outputs displayed in the paper frequently feature unclear layouts, inconsistent illustration, no clear colour palette, and often confusing meanings (see Figure 5.5). This is despite stating that experts were involved to ensure relevant design principles were adhered to. The design outputs had the potential to benefit from the adherence to the 20 design principles defined in chapter 4, and whose practicality is tested within this chapter.

Further evidence of this can be viewed in the infographics tested by Lunn et al., 2021, finding significant improvements in recall and comprehension compared to a written format. The infographics used were poorly designed with minimal use of any design principles (Figure 5.5). No significant difference in the ease of information adherence was observed between the groups, though the design of the infographic could have been considerably improved and may have led to more supportive results. Again, the infographics displayed in the publication by Hamaguchi et al. (2020) regarding COVID-19 infographic communication can be similarly interpreted (Figure 5.5). Though the infographic does apply some principles, the layout is confusing and the overall design has potential for improvement.

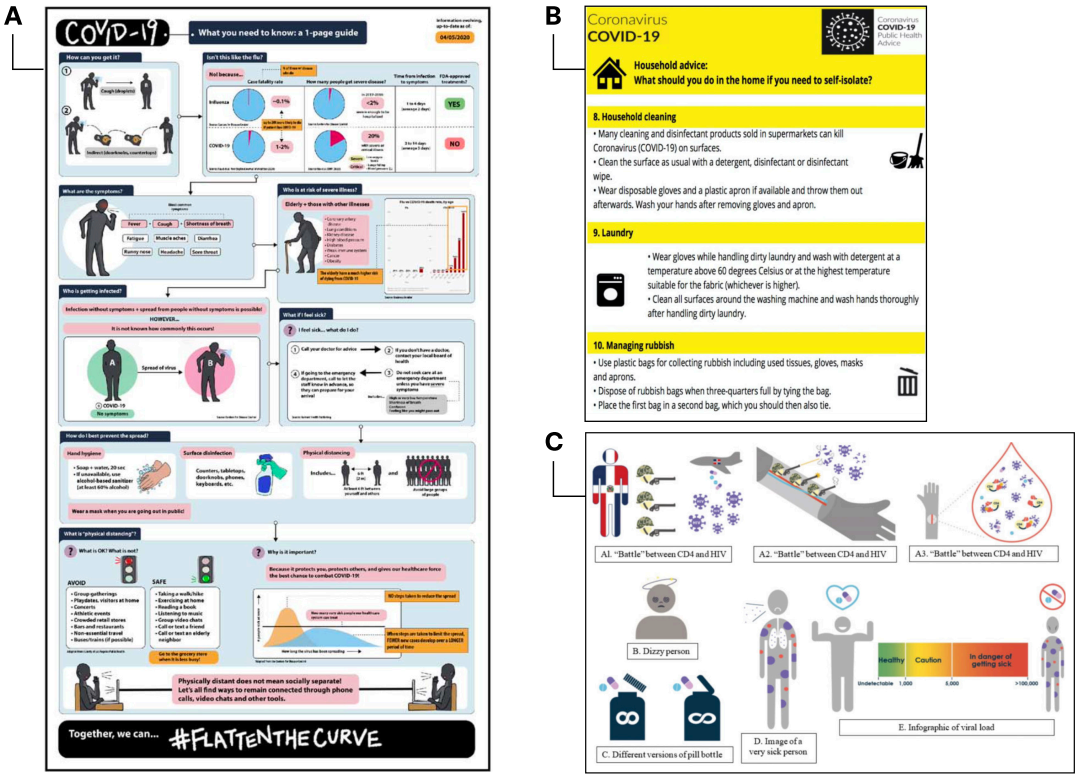


Figure 5.5. Infographics displayed or tested in COVID-19 infographic research publications that have the potential to be improved. **A** = Hamaguchi et al., 2020, **B** = Lunn et al., 2021, **C** = Stonbraker et al., 2019.

5.3.3 Introduction - Research aim

The aim, at this final research stage, was to investigate if design principle education had made an observable performance improvement to infographics created by healthcare professionals. As discussed, this improvement was measured by time to locate information, accuracy of recall, time to recall, and supported by opinion data. This was a comparative study with 2 groups, the first using 3 infographics from G1 that were designed with no other input, the second using 3 infographics from G2 after the education resources were accessed. As previously shown, the infographics from G2 applied an average increase in design principle application of 170.6%. It was hypothesised that the education resource produced a meaningful benefit to the infographics from G2, with improvements in the defined measures of effectiveness.

METHODOLOGY

It was hypothesised that the infographics developed after viewing the education motion graphic would be improved (as measured by information comprehension, location speed, and user opinion) due to the education of design principle application. Meaning, the second group would have faster information location times, more accurate recall scores, and more positive user experience feedback.

5.3.4. Methodology justification

This research determined the effectiveness of comparable infographics by measuring the information location speed, memorability of information, recall time, and user opinion. A similar method used to examine the infographics in the experimental research from chapter 3. However, eye-tracking was not employed as the research was conducted remotely due to COVID-19 limitations. Previous research has also used information location speed, memorability, and user preference data as measures of the effectiveness of visual designs such as infographics.

A comparative design research method was used by Lonsdale et al. (2019) to judge the effectiveness of security infographics and motion graphics on web pages when compared to the same information in a written format. The participants were asked to use the web page infographics by reading through the information, aiming to be representative of how the design should be used. The participants were timed to investigate how long it took to read the information. A similar method was again utilised by Lonsdale et al. (2020a) to evaluate the effectiveness of information visualisations, in the form of a booklet, motion graphic and mobile app, designed to educate medical patients. The participants were asked to locate the answers to questions that could be found within the design. Performance was measured by time to locate the information and comprehension accuracy, and supported by opinion data.

A similar method was applied by Wang et al. (2019) who used information memorability and user opinion as a measure of the effectiveness of infographics. To judge user opinion, they employed a questionnaire and asked the participants to rate 5 subjective design measurements on a Likert scale, including: aesthetics, exploration, fun, focus, and engaging. A similar approach was used in this study, employing an opinion questionnaire after the use of the infographics. However, the Likert scale questions aim to describe less subjective features of a design. Instead focusing on covering the perceived functionality and ratings of specific design features, such as colour and layout. They followed a similar methodology process to that used in this study; asking the participant to use the design, answer questions based on the design, then gather their opinion using a questionnaire.

Recall has also been used as a recognised measure of the improvement of health communication by using images (Houts et al., 2006). Houts et al. (2006) state that once a healthcare message is understood, it must be remembered for it to be used, suggesting recall as an effective assessment of knowledge acquisition. Given that the purpose of public health infographic is to educate a target audience on health information, recall was tested for rather than comprehension as this appeared to be a more appropriate measure of education.

Based on these existing methodologies, the present study asked the participant to use the designs by locating key information on an infographic. Followed by a recall test and opinion questionnaire. Performance was measured by time to locate information, accuracy of recall of this information, time to recall, and supported by the opinion data. Given that the core purpose of a public health infographic is to engage a user and efficiently educate on key health information (Scott et al., 2016), the timed location and recall accuracy of information appeared to be an appropriate task reflective of an infographics purpose. As acknowledged, these performance measures have been utilised by other researchers (e.g. Lonsdale et al., 2019; Wang et al., 2019; Lonsdale et al., 2020a) to compare the effectiveness of information visualisations.

5.3.5. Methodology – Participants

60 participants from the general public took part in the study. The participants were contacted via email if they were legible for the research, additional participants were recruited through contacts of the original participants. In order to be an eligible participant for the research the participant must be:

- Not working or studying as a healthcare professional.
- No colour blindness.
- Over 18 years of age.
- Have access to a stable internet connection.
- Have access to a laptop or personal computer with a webcam.
- Have a Microsoft Teams account.

Healthcare professionals and those studying in a healthcare field were excluded from the study. This is due to the heart attack content of the infographics; they would be more likely to have high levels of existing knowledge on this subject; potentially affecting the recall testing results. The personal detail statistics can be viewed below (Figure 5.6).

Although a slight gender bias was displayed between the two groups, with group 2 having more participants that identified as female, this did not impact the results of the study. An independent sample t-test was performed in both groups comparing gender with both information location time and recall accuracy. In group 1, there was no significant difference between male (M=135.255, SD=64.062) and female (M=161.313, SD=62.118) information location time; $t(30)= -1.131$, $p>0.05$, and no significant difference in male (M=4.827, SD=0.941) and female (M=4.493, SD=1.212) recall accuracy; $t(30)= 0.842$, $p>0.05$. Equally, in group 2, there was no significant difference between male (M=94.986, SD=8.483) and female (M=102.889, SD=16.749) information location time; $t(30)= -1.335$, $p>0.05$, and no significant difference in male (M=5.733, SD=0.837) and female (M=5.962, SD=0.582) recall accuracy; $t(30)=-0.863$, $p>0.05$. This provides evidence that gender had no observable impact on the results.

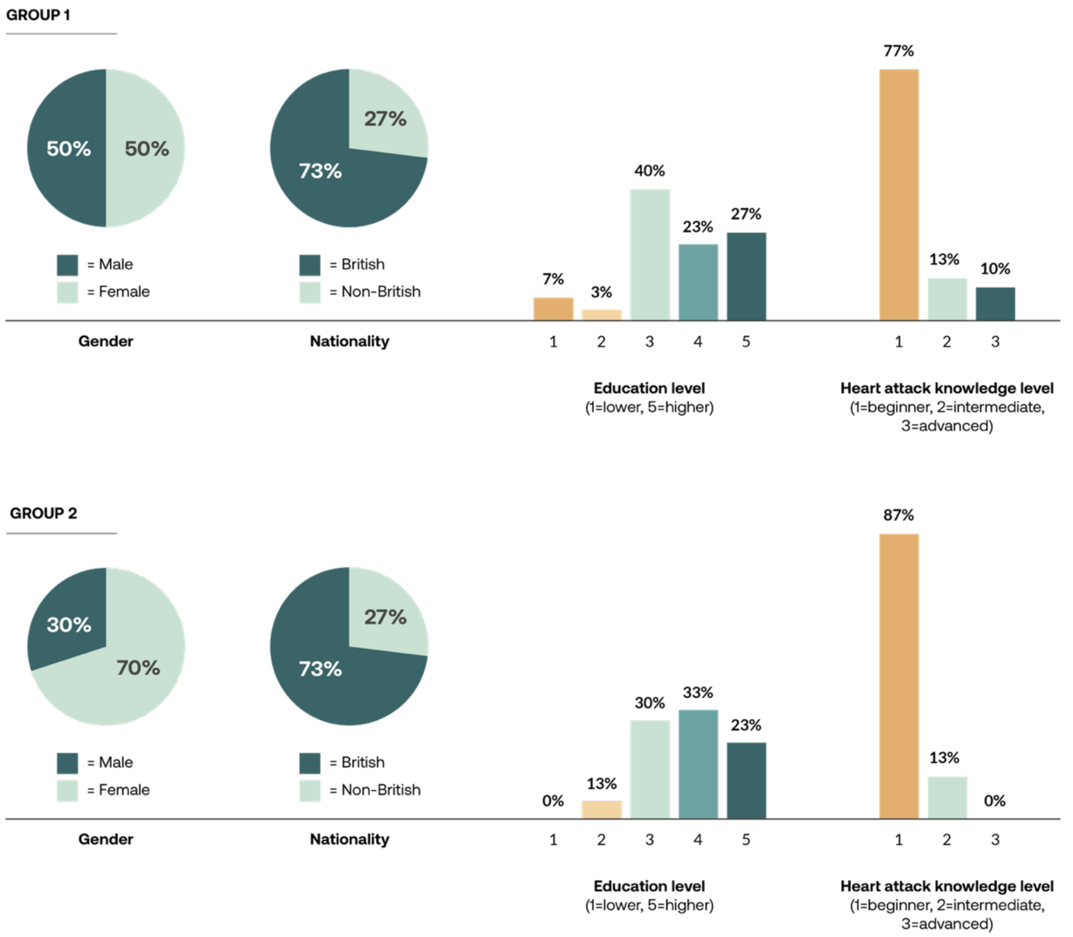


Figure 5.6. Graphs displaying the personal details of the 2 testing groups.

5.3.6. Methodology - Ethics

The participants were required to provide their consent with the collection and publication of their anonymised data to take part in the study. No personal details were collected that could be used to identify an individual participant. Part of the video call was recorded, with the consent of the participant, and permanently deleted after data transcription took place.

5.3.7. – Methodology - Experimental procedure

The 60 participants were randomly divided into 2 equal groups of 30 participants. The first group would be using the infographics developed by healthcare professionals with no prior design education (before using the motion graphic resource). The second group would be using the infographics developed by healthcare professionals after being educated on infographic principles using the motion graphics resource. Once assigned to a group the participants were then randomly assigned an infographic. 3 infographics were tested in each group meaning that each infographic was tested with 10 participants.

The experiment took place over video call on Microsoft Teams. First, the participant was asked to follow a link to a Google Forms document in an internet browser and asked to open it full screen. The Google Form was divided into 4 sections. First, the Google Form explained the data collection process with a consent section to ensure the participant understood the conditions of the study. This was repeated verbally to ensure understanding. If it was clear that the internet connection was poor during this stage of the call, making it difficult to communicate, the participant was made aware that the experiment could not take place and the call was ended. On the same form the participant was asked to fill in personal details that included the collection of their: age, gender, nationality, education level, and existing knowledge of heart attack information. Next, the participant was provided with both the definition of an infographic along with an example. They were told that they did not need to read through the infographic, instead it was to ensure they were familiar with what in infographic was before the experiment started. The final section of the Google Form explained the process of the experiment, this was repeated verbally to ensure the participant understood. It also contained a link that opened the infographic that they were using during the experiment. They were asked to ensure their internet browser was full screen so the infographic would be displayed the same for every participant.

Once the participant notified the researcher that the infographic was loaded the experiment started. The experiment was divided into 4 sections. Section 1 was an information location task where the participants were required to locate the answer to 7 questions, the answers to which could be located somewhere on the infographic. The questions were asked one at a time and the participant was asked to read the answer out loud to ensure they had located the correct answer. There was no time limit on the task and the next question was only moved on to once the answer was located; every participant correctly located 100% of the answers. This section was timed by the researcher, starting when the first question was asked and ending when the last answer was located. The participants were then asked to close the infographic they were using, submit the Google Form and return to the video call.

The second section of the experiment was an interview section that took roughly 3-5 minutes to complete. The purpose of this section was to provide a distracting task between the information location task and the upcoming short-term recall testing section, rather than to collect data. Previous research has used a similar technique in the testing of short-term memorability; implementing a task to distract the participant from the information they have just learned in order to test for short-term memorability as appose to comprehension (Bateman et al., 2010; Obie et al., 2019). The participants were asked the following questions and asked to describe their answers in detail:

1. Was there anything on the infographic that you found hard to find?
2. Was there anything on the infographic that you found hard to understand?
3. Do you think that infographics are a good way to communicate public health information?
4. Do you think the infographic you used was successful in teaching you about heart attacks?
5. What did you think of the design of the infographics you used?

The third stage of the experiment was a short-term recall testing section. The participants were asked the same questions they were asked in the information location task. They were asked not to guess the answers to the questions, and to recall the information they had just learned rather than any existing knowledge if possible. Again, there was no time limit and the participant was allowed as much time as they needed to recall the answers. In response to the inconclusive recall results from chapter 3, open questions were used as appose to multiple choice as the process reduces the possibility of correctly guessing answers (Kurz, 1999).

The final stage of the experiment was an opinion questionnaire. This was provided in a link to a second Google Forms document. The questionnaire was divided into 2 sections with the first exploring how well the participants thought the infographic functioned. The first looked to judge the functionality of the design, with the questions aimed at the purpose and engagement of the infographic. The participants were asked to agree/disagree to a statement on a 5-point scale with one of the following responses: 1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. Strongly agree. The statements were as follows:

1. The information was easy to find.
2. The information was presented in a way that was easy to understand.
3. The infographic was effective in teaching about heart attacks.
4. The infographic was memorable.
5. The infographic was attractive.

The second set of Likert scale questions looked to gather the participants opinion on the design features of the infographic that they used. The section asked them to rate how effective/ineffective they considered a feature on a 5-point scale, including: 1. Highly ineffective, 2. Ineffective, 3. Neutral, 4. Effective, 5. Highly effective. The features they were asked to rate are as follows,

1. Layout.
2. Colour.
3. Text and headings.
4. Graphics and graphs.
5. Overall design.

They were they asked to complete an adapted Microsoft Desirability Toolkit to describe their opinion on the design. This used the same 20 descriptive words (10 positive, 10 negative) from the experiment undertaken in chapter 3, with the participants asked to select 3 words that best described how they felt about the design. Finally, the participants were asked open questions to understand their opinion on what they thought was successful or what could be improved about the infographic they used. Once this questionnaire was submitted the study was complete.

RESULTS

Performance results

The information location time and information recall accuracy data were compared using independent sample t-tests. The 60 participants were designated to either group 1 or 2 with an individual participant only using a singular design, meaning the participants from each group were independent of one another. Given that the participants were also randomly assigned to 1 of 3 design variations within the grouping, one-way ANOVA tests were performed to examine any differences in information location or recall between the design variations.

5.3.8. Performance results - Information location

The participants located information significantly faster using the G2-after designs ($M=100.518$, $SD=15.063$), compared to the G1-before designs ($M=148.284$, $SD=63.400$); $t(30)= 4.015$, $p<0.001$ (Figure 5.7)

5.3.9. Performance results - Recall accuracy

The participants accuracy of information recall scores were significantly better using the G2-after design ($M=5.893$, $SD=0.662$), compared to the G1-before designs ($M=4.667$, $SD=1.085$); $t(30)=-5.289$, $p<0.001$ (Figure 5.8).

5.3.10. Performance results - Recall time

The participants also recalled the information significantly faster after using the G2-after designs ($M=106.819$, $SD=25.607$), compared to the G1-before designs ($M=125.941$, $SD=24.864$); $t(30)= 2.934$, $p=0.005$ (Figure 5.9).

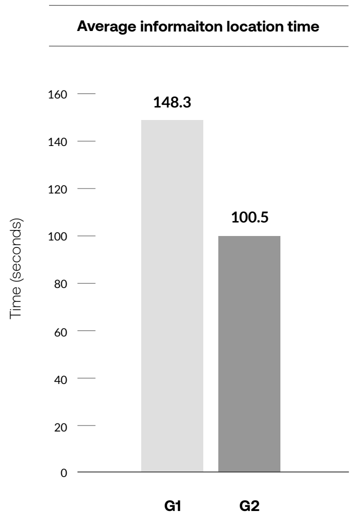


Figure 5.7 Comparing average info location time between G1 and G2.

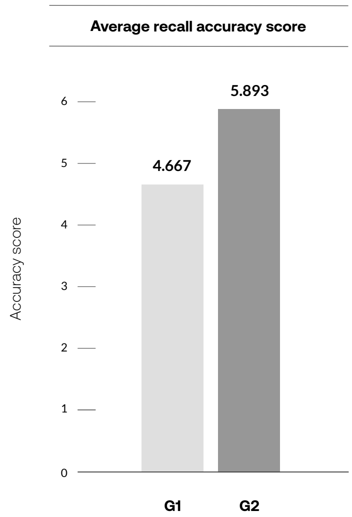


Figure 5.8 Comparing average recall accuracy scores between G1 and G2.

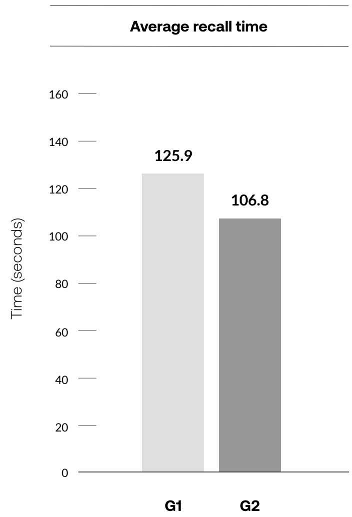


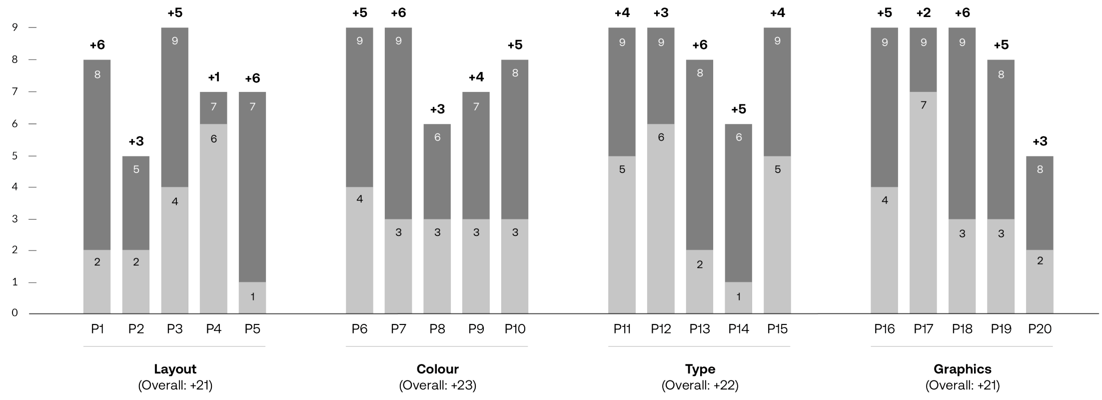
Figure 5.9 Comparing average recall time between G1 and G2.

A one-way ANOVA was performed to test for differences between the 3 design variations in both G1-before and G2-after. The one-way ANOVA for G1-before revealed that there was no significant differences between the design variations for both the mean information location time (F(2,27)= [0.007], p=0.993), recall accuracy scores (F(2,27)= [1.425], p=0.258), and recall time (F(2,27)= [0.068], p=0.934). The one-way ANOVA for G2-after also revealed that there was no significant differences between the design variations for both the mean information location time (F(2,27)= [0.023], p=0.977), recall accuracy scores (F(2,27)= [2.612], p=0.092), and recall time (F(2,27)= [2.323], p=0.117).

5.3.11. Performance results – Principle application analysis

Analysis was undertaken to compare the application of the 20 individual design principles between the infographics from G1 and G2. This is not statistically comparable analysis, but still investigates trends in principle application, revealing those principles that were most improved after the education resource was accessed. Results can be viewed in figure 5.10.

Principle improvement comparison



Principle improvement ranking

= Layout = Colour = Type = Graphics

+6

- **P1- Align elements -** Align your text and graphics to create an organised appearance, this can be achieved using a layout grid.
- **P5 - Connect information -** Connect related chunks of information and create a purposeful reading order using lines, arrows and numbers.
- **P7 - Clean backgrounds -** Use plain light backgrounds to reduce distractions, if in doubt use a white background.
- **P13 - Bold text -** Use bold or capitals to emphasise important words and information, be selective with its use.
- **P18 - Use pictograms –** Use these simple forms of graphics to ensure easy understanding; avoid complex graphics and images.

+5

- **P3 - Enclosure -** Enclose related information using coloured shapes or outlines, this can create information chunks that makes your design easier to remember.
- **P6 - Limit colour palette -** Choose a complimentary colour palette of 2 or 3 colours.
- **P10 - Colour coding -** Use colour purposefully to show information is related, by using the same colour for certain info.
- **P14 - Line spacing –** Increase the line spacing in paragraphs to make your information easier to read.
- **P16 - Simple design–** Make you design simple and consistent, using graphics that are easy to understand.
- **P19 - Object similarity –** Make objects visually similar if they are related. This can be done by matching visual elements such as colour, shape and size.

+4

- **P9 - Highlight important info -** Highlight the most important words or areas of information using a colour from your palette.
- **P11 - Simple fonts -** Use up to 2 or 3 simple fonts, a good tip is to use one font for the headings and another complimentary font for the headings.
- **P15 - Align to the left –** Make sure your lines of text fit to the left to optimise readability.

+3

- **P2 - Proximity -** Placing information close together suggests it is related. Use this to group related information into a chunk.
- **P8 - Text contrast -** Ensure colour contrast is high between the text and the background to make it easier to read.
- **P12 - Appropriate text size -** Ensure your text is the right size; smaller than your headings but still easy to read.
- **P20 - Appropriate graphs –** If you are using graphs, ensure they are easy to understand and match your colour scheme.

+2

- **P17 - Avoid decoration –** Remove decorative graphics and only use them if they are representing your written information.

+1

- **P4 - Noticeable headings -** Use headings to divide chunks of information. Make sure they are significantly bigger and bolder than the text body.

Figure 5.10. Principle improvement analysis to investigate the most improved of the 20 design principles.

Opinion results

5.3.12 Opinion results – Microsoft Desirability Toolkit

The descriptive word selection process resulted in clear differences between G1 and G2, the results can be viewed below in Table 5.1. In G1 37% of words chosen to describe the participants opinion on the design were positive and 63% of words were negative. The 5 most common words used to describe the G1 designs were: accessible, helpful, dated, hard to use, and time consuming.

In G2 96% of the words chosen were positive and 4% of the words were negative. The 5 most common words used to describe the G1 designs were: clear, accessible, straightforward, helpful, and calm. There is an observable difference here between G1 and G2; with the designs from G2 being described far more positively than those from G1, supporting the hypothesis of the research.

	G1		G2	
+ Positive	**Accessible**	**8**	**Clear**	**22**
	Helpful	**8**	**Accessible**	**13**
	Straighforward	4	**Straighforward**	**12**
	Clear	3	**Helpful**	**11**
	Effective	3	**Calm**	**7**
	Calm	2	Effective	5
	Reassuring	2	Reassuring	2
	Clean	1	Clean	1
	Easy to use	1	Easy to use	1
	Novel	1	Novel	0
– Negative	**Dated**	**13**	Confusing	1
	Hard to use	**12**	Hard to use	1
	Time consuming	**8**	Overwhelming	1
	Confusing	4	Time consuming	1
	Comlpex	4	Complex	0
	Discouraging	4	Dated	0
	Ineffective	4	Discouraging	0
	Overwhelming	4	Unhelpful	0
	Unhelpful	2	Ineffective	0
	Stressful	2	Stressful	0

Table 5.1. A display of the words selected to describe the designs from G1 and G2 using a Microsoft Desirability Toolkit.

G1 opinion results

5.3.13. G1 – Positives features of the designs

The participants were asked what they liked about the 'G1 – before' infographics. The participants liked that the information was broken up and not displayed just as a paragraph, and that there wasn't too much information. They also liked the use of images and graphs to represent the written information. However, the participants were not overly descriptive as it appears there was not a large amount of positive features of the designs in this group. Additionally, some participants stated there was nothing they liked about the designs.

5.3.14. G1 – Negative features of the designs

The participants were asked about anything they did not like about the 'G1 – before' infographics. The colours used were thought to be either boring or inappropriate. One of the infographics features a red background that most of the participants using commented on; stating they found it distracting or made them feel anxious. They thought the information on these designs was often poorly placed, with the most important information not effectively emphasised and the layout unclear. Some also considered the images unrelated to the information. It was also thought that there was too much information, despite the content being the same in all designs, and that the whole infographic had to be scanned in order to locate the correct information. The text was also said to be too small or hard to read by some of the participants.

G2 opinion results

5.3.15. G2 – Positives features of the designs

The participants liked the clean design style and calming use of colour in the 'G2 – after' designs, finding the reassuring tone appropriate for the potentially overwhelming health-based content. They thought the accompanying images were appropriately simple and made the information both easier to understand and remember. They also liked the layout of the designs, stating it made the information easy to scan and locate. They liked that it was not too text heavy, and the information divided into clear sections. Overall, the participants were much more descriptive about positive features of the 'G2 – after' designs and had much more to say about what they liked about the designs.

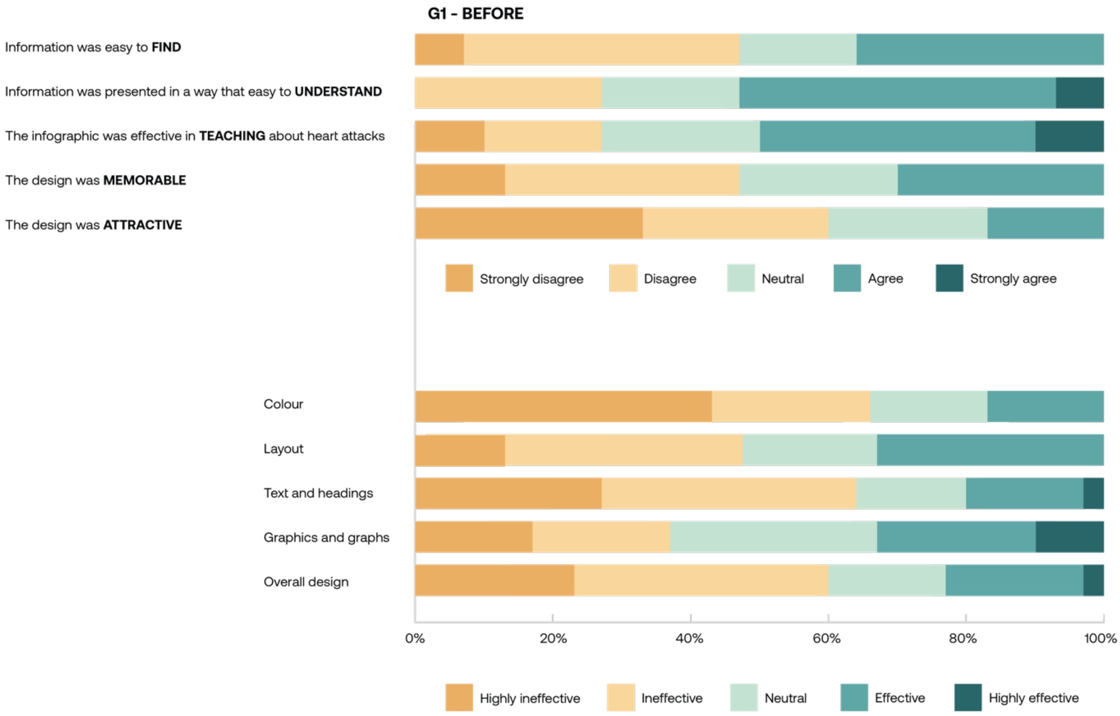
5.3.16. G2 – Negative features of the designs

Some of the participants thought that some of the more important information could have been emphasised more. They also thought that the statistics section was sometimes harder to read due to small text or small graphs. They commented that the definition of a heart attack section was sometimes too text heavy or placed in what appeared to be the wrong section. Some participants stated there was nothing they would change about the designs.

Likert scale

5.3.17. Results – Likert scale

The opinion questionnaire also asked the participants to answer a 5 question Likert scale rating the functionality of the infographic they used, and a second 5 question Likert scale rating their opinion on the design features. The results of the Likert scales for both G1 and G2 can be viewed in figure 5.11 below.



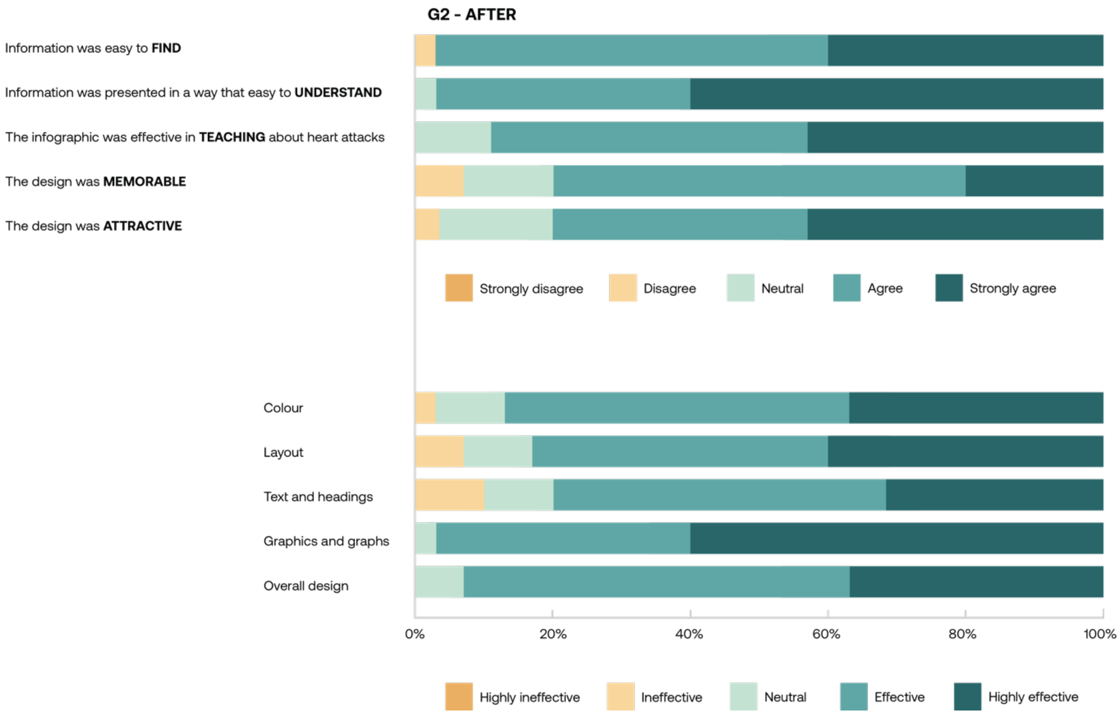


Figure 5.11. Displays the results of the likert scale questions asked in the opinion questionnaire for the participants using the designs from both G1 and G2.

5.4. Discussion

The results of the study find support for the hypothesis. This theorised that the design of public health infographics, created by healthcare professionals, would be improved after they had been educated on infographic design principles. The education process took the form of 4 motion graphic videos that explained 20 infographic design principles divided into the following categories: layout, colour, typography, and graphics; also supported by a principle summary pdf. In this study, improvement was measured by information location speed, information memorability and user preference. There were 2 comparative groups from this study. Group 1 (G1) used infographics that had been designed by healthcare professionals with no input. Group 2 (G2) used infographics that were designed by the same healthcare professionals, but in a secondary design stage after they had accessed education resources aiming to teach them how to use infographic design principles. It appears clear that the 20 design principles defined in chapter 4 can result in the design of effective infographics, and have a practical application in the education of non-designers.

5.4.1. Discussion - Performance results

Performance was calculated by 3 quantitative measures: information location time, information recall accuracy scores, and recall time. It was hypothesised that the participants from G2 would have faster information location times, higher recall accuracy scores, and faster recall times than the participants from G1. It was found that the information was located significantly faster by participants using the G2 designs, compared to G1. This provides evidence that successfully educating non-designers can result in the creation of infographics with information that is easier to locate. A performance measure that has previously been employed to explore the effectiveness of visual design (Lonsdale et al., 2019; Lonsdale et al., 2020a). The infographics from G1 and G2 displayed the same information in the same dimensions, so the only difference was the design of the information visualisation. Thus, clearly showing that use of the education resource resulted in the design of infographics where the location of information was significantly more efficient.

Information recall accuracy was also recorded. As described, there was a 3-5 minute interview task completed between the location of information and the recall tasks. In chapter 3, no significant findings were found in the comparison of recall accuracy between designs, aiming to investigate short and long-term memorability. It was suggested that instead immediate comprehension should be tested for, or that more questions should be asked to better investigate potential recall differences. Another problem may have been the long-term recall test was completed online without the researcher using a multiple-choice test, leading to potentially inaccurate results. To address this, short-term memorability was tested for using 7 questions instead of the 3 that were used in the assessment of memorability in chapter 3. Infographics exist to educate the user in an engaging easy to understand format (Scott et al., 2016). When considering the purpose of a public health infographic, the memorability appeared to be a stronger assessment of education effectiveness.

It was found that information was recalled significantly more accurately by participants using the G2 designs, compared to G1. Supporting findings were also found here by comparison of recall times. The participants were also timed during the recall experiment, the participants in G2 recalled the answers significantly faster than the participants from G1. So, information was not only recalled more accurately, it was also recalled significantly faster. Recall speed has previously been utilised as a complimentary evaluation of memory performance (e.g van den Broek et al., 2014; Keresztes et al., 2014; Racsmány et al., 2018), and in combination with recall accuracy has been suggested as an appropriate measure of memory accessibility (Kubik et al., 2018). Therefore, finding further evidence of the superior memorability of information displayed in by the G2 designs.

The infographics tested in both G1 composed of 3 different variations, with G2 testing another 3 variations created by the same designers after using the education resources. It was a possibility that some variations within G1 may have performed better or worse than others, this also being applicable to the designs with G2. Consequently, one-way ANOVA tests were ran to investigate any potential differences. The one-way ANOVA for G2 revealed that there was no significant difference between the design variations for both the information location time and recall accuracy scores. This suggested that all the G2 designs performed equally, with no one design more effective than another. This was also true for the G1 designs; the one-way ANOVA for G1 again showed that there was no significant difference between the design variations for both the information location and recall scores. This analysis showed that there was not a specific design variation that disproportionately affected the results of the research. For example, there was not one disproportionality highly or poorly performing design variation from either group that may have skewed the results. Instead, it provides evidence that every design in the G2 group performed better than every design in the G1 group.

Additional analysis was undertaken on the application of the 20 infographic principles that the healthcare professionals were asked to use in their second design outputs. The difference between the frequency of application between the G1 and G2 designs was calculated for each individual principle, aiming to identify the principles that were most improved. As expected, every principle was applied more frequently in the second stage of infographic design (after using the education resource). This analysis aimed reveal those principles that were most improved and, thus, may have provided the greatest benefit to the improvement in effectiveness observed in the G2 designs.

It is important to note that this analysis does not determine the most important principles, as some of the most impactful principles may be those that were already applied by a greater number of the participants in the initial design stage. Instead, this identifies principles that are typically not applied by non-designers, that the teaching resource allowed them to apply, resulting in more effective infographic outputs. In other words, the principles that may have had the most beneficial impact on the secondary infographic outputs. Figure 5.10 shows the most improved principles. These principles may be the principles that had the greatest impact on the improvement in effectiveness in the G2 infographics.

The analysis also compared the principle improvement between the principle categories (layout, colour, type, graphics), to determine if any one category appeared more important than another. The resulting principle improvement between the categories were: layout: +21, colour: +23, type:+22, graphics: +21. As shown, the improvement appears to be very consistent across all four principle categories. This would imply that each category is of similar importance, and emphasises that all four of these categories of design need to be taken into account in the infographic design process in order to maximise effectiveness. As shown, there also appears to be an even spread between the design categories for which principles appear as most improved (+6 and +5 category), again providing evidence of the similar importance of each category.

5.4.2. Discussion - Opinion results

The qualitative results, collected in the opinion questionnaire, support the positive quantitative results. The findings further confirm the hypothesis, with the infographics from G2 positively received compared to the mixed response to the G1 infographics. Figure 5.11 shows the results of the Likert scale section of the questionnaire. When observing the Likert scale functionality results, the response to the G1 infographics were mixed. Most of the participants either strongly disagreed, disagreed or were neutral to the statements that the infographics from G1 had information that was easy to find, memorable and attractive. Most of the participant using the G1 designs were neutral or agreed with the statements that the info was easy to understand, or effective in teaching; though over 20% disagreed with the statements. Notably, the majority of participants disagreed or strongly disagreed with the statement ‘the infographics were attractive’; providing evidence that the infographics from G1 were considered aesthetically unappealing.

A similar pattern is observed when looking at the Likert scale design feature results. The majority of every design feature measured (layout, colour, text and headings, graphic and graphs, and overall design) were rated as highly ineffective, ineffective, or neutral. The design features of colour, text and headings, and overall design were particularly poorly received. Overall, the responses indicate that the participants using the G1 infographics considered their functionality mixed and the design features relatively poor.

Typically, the response to the G2 infographics was more positive. When considering the functionality of the designs, the majority of participants agreed or strongly agreed with all 5 statements (Figure 5.11). This was also true of all 5 design features with the majority of participants considering them effective or highly effective, with the graphics and graphs being especially highly received. The responses indicated that the participants using the G2 infographics considered them functional and well designed.

The infographics from G1 were considered unattractive but those from G2 attractive; this is an important distinction between the designs from each group. Previous research has established that more aesthetically pleasing designs are considered more usable (e.g. Tractinsky et al., 2000; Robins and Holmes, 2008; Sonderegger and Sauer, 2010). Research by Harrison et al. (2015) examined this finding in the context of infographics, finding reliable opinions of a designs appeal is formed within half a second of its initial viewing, and concluding that engagement and memorability may be determined by visual first impressions. This would suggest that the G2 infographics, designed after the creators were educated to apply infographic design principles, may be considered more engaging and useable. Given that the core purpose of a public health infographic is to educate the public on key health messages, the judged attractiveness and usability ratings appears to be an important feature.

The results of the Microsoft desirability toolkit were also reflective of the Likert scale results. G1 was described with 37% positive and 63% negative words, the 5 most popular being: accessible, helpful, dated, hard to use, and time consuming. G2 was described with 96% positive and 4% negative words, the 5 most popular being: clear, accessible, straightforward, helpful, and calm. Results can be viewed on Table 5.1.

Again, the interview questions also found comparable findings. The participants using the G1 infographics found the colours boring or inappropriate, with confusing layouts and often poorly placed elements. The important information was also thought to be ineffectively emphasised, and using unrelated imagery. Some participants also stated there was nothing they liked about the designs. The participants did like that the information was broken up and represented with images. Generally, however, the designs were thought to be unattractive and hard to use. The participants using the G2 infographics were more positive. They considered the tone of the designs appropriate for the content, using clean and calm colour schemes. The layouts were thought to be easy to scan, with the information divided into clear sections and using simple images. Though, some of the graphs were thought to be hard to use due to small sizing or text.

The qualitative results display clear evidence of a more positive user response when using the G2 compared to the G1 infographics. The G2 designs were considered more attractive, functional, and better designed infographics resulting in a and a more clear, straightforward and calming emotional response. Perceived aesthetic and usability ratings can be an important factor in the willingness to engage with a design (Tractinsky et al., 2000; Seo et al., 2015; Lau et al., 2021), so this evidence supports the finding that use of the education resource resulted in more effective design outputs. Based on both the quantitative and qualitative results, there appears to be clear evidence that the infographics from G2 were better performing than those from G1.

5.4.3. Discussion - Links to existing research

The results of the study confirm the hypothesis that the education resource produced a meaningful benefit to the infographics from G2, with improvements in the defined measures of effectiveness. The G2 infographics were found to be significantly faster to locate information on, more memorable, and rated higher in user opinion measures than the infographic from G1. The only difference between the designs generated by G1 and G2, was that the infographics from G2 were created after the participants viewed 4 educational motion graphics covering 20 core infographic design principles. This provides evidence that both the use of design principles results in more effective public health infographics, and that the design principle education of non-designers using motion graphics is a valid approach to improve this popular visualisation method.

Public health infographics have played a key role in the dissemination of COVID-19 information (Chan et al., 2020; Hamaguchi et al., 2020), and have been shown to be effective in inciting positive public behavioural changes in regards to the pandemic (e.g. Crutcher and Seidler, 2021; Egan et al., 2021; Lunn et al., 2021). Although the effectiveness of infographics has been recognised, minimal research has currently been published on practical approaches of creating effective designs, despite this need being acknowledged (Scott et al., 2017; Kemp et al., 2021). Infographic principle application have been recognised and defined by multiple publications (Stones and Gent, 2015a; Lonsdale and Lonsdale, 2019; Hernandez-Sanchez et al., 2021), and shown to be a method to improve the effectiveness of public health infographics (Baxter et al., 2021).

As previously recognised, however, design principles are difficult to follow for those with limited design experience. As exemplified in multiple COVID-19 infographic related publications, where the infographics tested have multiple opportunities for design improvement (e.g. Stonbraker et al., 2019; Hamaguchi et al., 2020; Lunn et al., 2021). The findings of this research present a practical method for to use of infographic design principles for the education of the creators of infographics from a non-design background, such as healthcare professionals. The results of the study find clear evidence that the motion graphic education process resulted in the design of significantly more effective infographics. Currently, this is the first known publication presenting a practical solution to improve the effectiveness of public health infographics using design principles. Consequently, education motion graphics are recommended as tool to improve the effectiveness of public health infographics.

Research in the field of motion graphics is not extensive. Despite this, the available literature has shown that motion graphics can reduce cognitive effort required to understand information compared to static graphics (Hsueh et al., 2016). Meta-analysis has suggested that motion graphics are a more effective teaching tool than static graphics in an instructional context (Höffler and Leutner, 2007). They have also been recommended as an effective learning tool in a student education setting (Wiana et al., 2018; Hapsari and Hanif, 2019). In a broader field, described using the more general definition of 'videos', videos have been shown to support education by increasing student engagement (Choe et al., 2019) and satisfaction (Hsin and Cigas, 2013). The results of this study find further support for the use of motion graphics in an education setting, backing the conclusions of these publications. Here, they were utilised to teach complex design concepts and application to an audience with limited experience in the field. Suggesting a meaningful level of knowledge acquisition through this format. Feedback from the target audience, healthcare professionals, also found the format both engaging and easy to follow. The research findings from chapter 4 and 5 contribute to this underdeveloped field, showing motion graphics as an effective method to educate non-experts on complex practical concepts.

It also finds evidence for both the application of design principles and a user-centred design process for motion graphics. Here, showing this process can achieve design outputs effective in their education-based purpose. Multiple recent publications by

Professor Maria Lonsdale have tested health-based motion graphics developed in this iterative user centred process (Lonsdale and Liao, 2018; Lonsdale et al., 2019; Lonsdale et al., 2020a). Results have found significant improvements in knowledge acquisition after viewing motion graphics (Lonsdale and Liao, 2018), as well as significantly improvements in patient information comprehension accuracy and user opinion when compared to a text-dense static format (Lonsdale et al., 2020a). The motion graphics from chapter 4 were designed using the same process, presenting further evidence for the success of this design process.

The study has established an effective method of improving public health infographics, additionally, this finding may be applicable to other fields. Though currently untested, there is potential for this motion graphic principle education process to improve the design of infographics in areas they are commonly used, such as public security information, safety campaigns, business statistics, and journalism. Infographics have been shown to improve learning performance in fields other than health, including public security information (e.g. Lonsdale et al., 2019). There is also potential for the improvement in specific uses such as publication abstracts, and infographics that are the subject of experimental testing. As discussed, infographics are recently becoming the subject of experimental testing (e.g. Wang et al., 2019; Crutcher and Seidler, 2021; Egan et al., 2021) and have been shown to improve research publication engagement (Kunze et al., 2021). Given their use is becoming widespread across many fields in multiple contexts, the simple motion graphic series developed here to instruct effective infographic design may prove a useful resource. Although the research focused on participants from a non-deign background, there may also be some potential for benefit of designers too. As observed in research by Stonbraker et al. (2019), the infographics developed in the study were said to be designed by experts; though the final infographic outputs appear to have considerable potential for improvement. Further research is required to confirm benefit in the application to other fields and target users.

5.4.4. Discussion – Research limitations

A possible limitation of the research lies in the distribution of the findings. The research has shown that the motion graphics developed were effective in their purpose. Currently, however, they are hosted on an online video sharing platform with minimal engagement. To make the findings impactful to the free development of public health infographics may require a more accessible and engaging distribution method. Future work looks to display these videos on a bespoke website, allowing the motion graphics to be freely accessed in on a user-friendly hosting platform. This could help maximise the circulation of the education resource, with the potential the positively impact the future development of infographics, in both public health and other applicable fields.

A further limitation of the research presents itself in the fact that the infographics tested were not compared against a control group that use the information in a basic written format. However, previous research has already established that infographics are more effective than the same information in a written format (Lonsdale et al., 2019), even in the field of public health infographics (Egan et al., 2021; Lunn et al., 2021). A final limitation in the findings of the quality of the infographics developed after using the motion graphics could still be improved in certain aspects. However, it is demanding to expect an individual with very limited design experience, such as a healthcare professional, to produce an information visualisation to the same standard as an experienced information designer. Realistically, infographics are going to continue to be created by those with limited design experience; an education resource such as this may be an appropriate solution to help maximise the effectiveness of the inevitable design outputs.

5.4.5. Discussion – Summary and significance of findings

The overall aim of the chapter 4 and 5 of this project was to develop and test a method of infographic principle education that could be utilised by non-designers, and result in the creation of effective public health infographics. Based on the findings of this chapter, it can be concluded that this aim was successfully addressed. The motion graphic videos developed in chapter 4 were shown to result in more effective infographic designs, when compared to infographics that had been developed previously by the same participants with no other input. Feedback on the motion graphics by the 9 healthcare professionals that accessed them found them to be easy to follow, well designed, and a resource they would look to use again if required to design infographics in the future. Evaluation of principle application also showed, on average, that 7.7/20 principles were applied before accessing the education resource, and 17.2 principles were applied in the infographics after; resulting in an average increase of 9.5 principles or 170.6% improvement. The infographic outputs can be viewed in Figure 5.2. The 3 most improved outputs were taken to an experimental testing stage, aiming to explore if the education process had resulted in the development of more effective designs (as measured by information location speed, recall memorability, and user opinion).

During this second stage, 60 participants were recruited for a study that equally divided the participants into those using the 3 infographics developed with no input, and those using the infographics developed after accessing the education resource. The participants were asked to locate information on the infographic they were using, later required to recall what they learned, and finally their opinion collected through a questionnaire. It was hypothesised that the infographics developed after accessing the education resource would be more effective. The results were supportive, finding the infographics in G2 resulted in significantly faster information location, significantly higher recall scores, and reflective qualitative results with more positive user opinions; when compared to the G1 infographics.

This research found important practical evidence for the use of design principle education resources, specifically using a motion graphic format. As reviewed, infographics have been promoted for their effectiveness in public health communication, and design principle application as a method to make these designs more effective. At point of writing, this remains the first experimental research conducted that considers how to maximise design principle adherence to improve the effectiveness of public health infographics. Here, achieved through educating healthcare professionals with limited design experience. If this motion graphic education resource is effectively distributed, it has the potential to improve the effectiveness of infographics displaying important public health information. Practical application could be used to optimise the communication of key public health messages, such future COVID-19 communications.

6. Discussion

6.1. Summary of research problem

The effectiveness of infographics to communicate complex information has been recently recognised in numerous contexts. Including: academic abstract visualisation (Huang et al., 2018a; Thoma et al., 2018), public security (Lonsdale et al., 2019), patient education (Balkac and Ergun, 2018; Provvidenza et al., 2019), science information (Otten et al., 2015), and healthcare communication (Patel et al., 2020). This method of information visualisation has been shown to significantly improve user performance when compared to the same information in a non-visualised format (Lonsdale et al., 2019). Research efforts have recently began focusing on the use of infographics in the context of public health information (e.g. Chan et al., 2020; Hamaguchi et al., 2020; Kemp et al., 2021), specifically researching their important role in the dissemination of COVID-19 information (e.g. Crutcher and Seidler, 2021; Egan et al., 2021; Lunn et al., 2021). Given the recent reliance on infographics to display public health information, effective designs appear to be of importance. As shown in the first research study presented in this thesis (Chapter 3), poor application of infographic principles can result in significantly reduced infographic communication effectiveness.

Kemp et al. (2021) recognise, in their own publication, that design practices to ensure the effectiveness of COVID-19 related infographics are rarely considered in research. Interview data by Stones and Gent (2015b) also revealed that infographics created by public health organisations are frequently designed, not by a specific infographic designer role, but by individuals with limited design experience and inadequate design software. This may explain some of the apparent lack of design quality suggested by the infographics published by the NHS (as seen in the introduction). This was supported by interview data from the second research study of this thesis (chapter 5), that recorded that 9/9 of the healthcare professionals recruited in that stage of research had been required to produce health-related infographics for work or during their training. These infographics were displayed in public spaces including hospitals and medical research conferences. The problem presented here is that non-designers are highly likely to continue producing public health infographics, the effectiveness of which will be variable given the lack of design experience by this demographic. This here presents a problem that was identified in the project; that infographics are published in an important field of communication that overlook design principles.

The potential solution to the problem that is explored in this thesis lies in the utilisation of research-based infographic design principles. These are design guidelines established through relevant literature that, when appropriately applied, can improve the effectiveness of the design outcome. As previously discussed, infographics design principles have both been established in the literature (e.g. Stones and Gent, 2015a; Dunlap and Lowenthal, 2016; Lonsdale and Lonsdale, 2019; Hernandez-Sanchez et al., 2021), and recommended as a means to create effective designs (Otten et al., 2015; Lonsdale et al., 2019). The use of design principles has also been shown to increase engagement in e-learning materials (Mulqueeny et al., 2015), and knowledge acquisition in the context of both patient leaflets (McKenna and Scott, 2007; Lonsdale et al., 2020b) and multimedia information presentation (Issa et al., 2011; Pate and Posey, 2016), as well as improving short-term information memorability and speed of information location on webpages (Lonsdale et al., 2019). Consequently, the use of design principles was presented as a means to ensure the effective design of public health infographics. The project investigated what current principles exist, and if their application results in more effective infographics. Later exploring what resource would be appropriate to educate non-designers on these principles, and if this resource resulted in more effective infographic outputs by this demographic.

As previously emphasised, the ‘effectiveness’ of an infographics is measured by a number of parameters related to the core function of an infographic, which is to engage and educate the target user on a chosen topic using an accessible format. These parameters were as follows: the speed of information location, the memorability of information, and user opinion (including judgement on engagement, function, and quality of specific design features). Previous research has also used information location speed (e.g. Lonsdale et al., 2019; Lonsdale et al., 2020a), memorability (e.g. Houts et al., 2006; Wang et al., 2019; Lonsdale et al., 2019) and user opinion/preference (e.g. Lonsdale and Lonsdale, 2019; Wang et al., 2019) as the measures of effectiveness when comparing various designs.

6.2. Summary of findings

The project was divided into 4 chapters, as summarised below:

- **Chapter 2** – Definition of infographic design principles from research-based literature.
- **Chapter 3** – Development and performance comparison of 3 public health infographic outputs that apply these design principles in varying quantities ('good', 'average', and 'poor' designs).
- **Chapter 4** – Development of an education resource, in the form of instructional motion graphics, that aimed to teach non-designers how to apply design principles when creating infographics.
- **Chapter 5** – Practical testing of the education resource. First, using an heuristic generative design process with healthcare professional allowing them to design infographics before and after accessing the resource. Next, experimentally comparing the general public's performance with the outputs.

Chapter 2 of the project aimed to establish relevant infographic design principles. This was addressed through the completion of a literature review that focused on research-based design principles, rather than practice-led guidelines. Research publications specifically investigating features of infographics design are limited, so the review covered a variety of research fields applicable to infographics. These included: human cognition, Gestalt theory, layout and structure, colour, typographic, and graphic design. The subsequent review resulted in the definition of 84 infographic design principles. It was hypothesised that the application of these principles would result in a meaningful improvement in the effectiveness of public health infographic design. As defined within the project, 'effectiveness' was determined in this research by the following performance measures: information location speed and accuracy, memorability of information, and user opinion; common performance measures in the field of information visualisation (e.g. Houts et al., 2006; Lonsdale and Lonsdale, 2019; Wang et al., 2019; Lonsdale et al., 2020a).

Chapter 3 aimed to investigate if the application of the previously defined principles resulted in an improvement in the effectiveness of public health infographics. First, a scoping questionnaire was completed to understand if the categorisation of infographics into ‘good’, ‘average’ and ‘poor’ based on the application of design principles was reliable. The questionnaire was completed by 35 designers and 35 participants from the general public, and were asked to rate the quality of layout, colour, typography, graphics, and overall design of 15 infographics (5 from each category). Thus, a secondary aim of the questionnaire was to understand if public health infographic design is interpreted similarly by both demographics. Similar interpretation would suggest knowledge of design theory is not explicitly required to interpret the quality of certain infographic design features. As expected, the results generally found that the ‘good’ infographics were highly received, the ‘average’ had a mixed reception, and the ‘poor’ infographics were poorly received. Designers and the general public perceived the infographics similarly, though the designers were more critical likely due to their understanding of design underlying processes. The results suggested that categorisation of public health infographics based on the application of design principles was a reliable measure of the quality of the design features. This also justified further research in the next stage which looked to statistically compare quantitative data of infographics within these 3 categories.

In this second stage of the chapter testing resources were first developed. This took the form of 3 different public health infographic designs, categorised as ‘good’, ‘average’, and ‘poor’. The ‘good’ infographic was designed to apply 84/84 principles, the average 42/84, and the poor design 1/84. The principles used in the ‘average’ design was informed by a design feature analysis that surveyed for the most common design features used in 56 existing infographics, aiming to make the ‘average’ design representative of an average infographic. The testing resources were created, as appose to using existing infographics, to allow control in both the number of principles applied as well as the content of the designs. Usability testing was also employed to address any design flaws in the ‘good’ design before testing. These 3 categories of infographics were then tested in a comparative study using 30 participants from the general public. Both quantitative performance and supporting qualitative data was collected; this compared the speed of information location, short and long-term information memorability, and user opinion data. Eye-tracking software was also used to collect fixation and heat map data, allowing further analysis of information location speed and areas of interest on the designs. Results found participants using the ‘good’ design displayed significantly faster information location speed and required significantly fewer fixation points to find the desired information, when compared to the 'average' and 'poor' design. Thus, finding evidence that the more design principles applied the more effective the public health infographic. This was supported by the opinion data with the highest ratings again recorded for the 'good' infographic.

The forth chapter of the thesis intended to apply these findings; it had been shown that utilising a high proportion of design principles in the infographic design process resulted in more effective design. Consequently, this was linked back to the target audience of the project and aimed to find a way to allow non-designers to use these principles when creating public health infographics. This began by addressing a problem that was identified, in that it was unrealistic to ask a non-design audience to adhere to 84 complex design principles. So first, a 3-stage process was employed to reduce the number of principles whilst retaining the most pragmatic guidelines. Stage 1 saw a logic-based analysis that removed principles that were too general, subjective, or impractical. Next a basic form of exploratory factor analysis was used to group related principles into a single streamlined principle. Lastly, data from the analysis of 'good' infographics was used to identify the most salient principles, along with a second round of principle grouping. This reduced the number of principles from 84 to 20, they were then divided equally into 4 categories (layout, colour, typography, and graphics).

Given the overall aim of the chapter, next, an education method was explored that could teach non-designers how to successfully use these 20 reduced principles. Consultation of the literature revealed motion graphic videos as an appropriate method to achieve this, due to their engaging format and their proven knowledge acquisition effectiveness. Further review of the literature defined motion graphic design principles that were adhered to in the design process to optimise the output. Consequently, 4 motion graphic videos were designed including the 4 sets of 5 principles covering layout, colour, typography, and graphic design. An iterative user-centred design approach was utilised, employing 2 stages of usability testing with both information designers and healthcare professionals (non-designers), to ensure the videos addressed the needs of the future users. The motion graphics aimed to explain each principle in a step-by-step process, using an example infographic that was improved using each principle throughout the videos. A complimentary pdf was also created to summarise the principles covered, as supported by the usability testing. The final education resource, consisting of the motion graphic series and summary pdf, aimed to teach non-designers how to use the 20 infographic design principles.

The final chapter of the thesis investigated the potential benefit of the education resource by experimentally comparing infographics had been designed by healthcare professionals before and after accessing the resource. This chapter was divided into 2 parts. Due to limitation posed by COVID-19, the research in this stage was conducted remotely. The first was a heuristic generative design method that generated infographic outputs after non-designers had accessed the resource. As previously recognised, public health and healthcare professionals may be responsible for the generation of openly available public health infographics. Consequently, this stage of research recruited this demographic and first required 9 healthcare professionals to design a heart attack infographic with supplied information and graphs, with no external assistance. The researcher was available for assistance with the design software throughout the process. Next, after a 7-day break, the same participants were asked to repeat the process, but this time after accessing the education resource. Participant feedback on the resource was overwhelmingly positive. Initial analysis of the infographics that were generated in both groups revealed that an average 7.7/20 principles were applied in the infographics created by the healthcare professionals in the first design generation stage. In the second stage, after using the resource, an average of 17.2/20 principles were applied; resulting in an average increase of 9.5 principles or 170.6% improvement. These results suggested that use of the education resource successfully improved the infographics.

The second part of chapter 5 aimed to experimentally compare performance with the infographics developed in the first stage of the study. The infographics created after the healthcare professionals accessed the education resource had already been shown to apply more design principles. Consequently, it was hypothesised that the infographics created in the second design generation stage would be more effective than the first (that were created with no input). The designs of the 3 healthcare professionals that showed the most improvement before and after using the resource were taken to the testing stage, in order to examine the greatest potential benefit the resource could have. 60 participants from the general public were recruited and randomly assigned to 1 of 2 equal groups. Group 1 used the 3 infographics that were designed with no input, group 2 used the designs that were generated after the education resource had been accessed. The results were supportive of the hypothesis, finding the infographics in group 2 resulted in significantly faster information location, significantly higher recall scores, and reflective qualitative results with more positive user opinions, when compared to the group 1 infographics. The qualitative opinion data that was collected supported these findings. The G2 designs scored highly in both the design feature ratings (layout, colour, text, graphics, and overall design) and the functionality ratings (easy of use, understanding, teaching effectiveness, memorability, and attractiveness). A vast majority (96%) of the words used to describe the designs in the Microsoft Desirability Toolkit testing were positive. The G1 infographics scored poorly in design feature ratings and had a mixed response to functionality, with a majority (63%) negative description of the designs. This suggests that the education resource was successful in its purpose to teach the target audience how to generate more effective public health infographics.

It was also identified that each category of design covered in the motion graphics (layout, colour, type, graphics) had comparable impacts on the improvement to the G2 infographics, so appear to be of equal importance. Analysis also revealed that there were some principle already applied in high proportions, showing that healthcare professionals already had some base knowledge of design principles without any formal education on the subject. Additionally, the principles that were most improved were identified; these may have had the largest impact on the observed improvements in effectiveness as a consequence of the infographic principle education.

6.3. Impact and contribution to knowledge

The findings of the project addressed the research questions presented in the introduction. First, chapter 2 defined the design principles applicable to infographics at the time of assessment in an extensive literature review that consulted the applicable fields. Next, in Chapter 3 evidence was found to suggest that the application of design principles creates a meaningful improvement in the effectiveness of public health infographic design. In Chapter 4, it was recognised that adherence to a complex list of 84 design principles was unrealistic for the non-designer target user. Thus, the principles were condensed to 20 using a 3-stage reduction method to retain the most pragmatic principles. To maximise engagement and understanding of these principles, a series of motion graphics was developed to teach non-designers how to use these principles in their own design process. Finally, Chapter 5 examined the practicality of the motion graphics to investigate if the use of the resource could improve the effectiveness of public health infographic design by non-designers. Healthcare professionals created infographics before and after using the education resource, and the design outputs were compared in an experimental study. Results finding that the education of non-designers, using these motion graphics, resulted in significantly more effective public health infographic design. This identified both a successful method for effective design education tool development, and a specific education tool for integration within healthcare professional education to benefit the future output of public health infographics

6.3.1. Chapter 2 impact

In Chapter 2 of the project, an extensive literature was conducted to define 84 infographic design principles. Due to the limited research into specific infographic design principles, multiple applicable fields were consulted including: human cognition, Gestalt theory, layout, colour, typographic, and graphic design. This included the careful collection, interpretation, and summarisation of a large body of research-based publications. This was a time-consuming process involving the critical interpretation of a research publication to evaluate the legitimacy of the methods used, the strength and suitability of the statistic findings, and the accuracy of interpretation of the results. Additionally, the publications considered in the literature review rarely specified the design principle(s) that could be derived from their findings, particularly in the context of infographics. As discussed, the literature review had to consider other applicable fields given the current lack of empirical research in infographic design practises. To summarise, the literature review critically analysed the research that was considered, then carefully interpreted the findings in the context of infographics, finally distilling these findings into detailed rules that could be applied to infographics. These principles, if applied, increase the chance of reaching an effective design solution.

This literature offers a contribution to the knowledge in the field of infographics by collecting and interpreting this breadth of applicable research. The resultant list of 84 infographic design principles can be applied in the infographic design process to generate more effective, accessible, memorable, and engaging designs. Thus, it is a valuable resource for experienced information and infographic designers looking to maximise the effectiveness of their infographic outputs. This list of principles is a highly detailed summary of infographic principles with the potential to benefit future infographic design if correctly followed. Though it may be difficult to use for individuals without appropriate education and experience in the field of information design, it has the potential to improve the highly used infographic format if utilised effectively.

This list of design principles could also be used to direct future research into infographic design, by offering a summary of practices that have been researched, potentially directing research to areas yet to be considered. They could also be adapted for other uses such as education resources aimed at designer requiring specific knowledge of infographic design, or principles for other related design outputs such as web design, interactive infographics, or instructional materials.

6.3.2. Chapter 3 impact

The findings of Chapter 3 were published in the Information Design Journal (Baxter et al., 2021). At the time of publication, this was the first study to find specific evidence that the application of design principles results in more effective public health infographic design. Though this may appear an obvious outcome, it was important to find evidence of this before continuing with the project. Without explicit proof, it was only assumed that design principle adherence would improve the effectiveness of public health infographic design. Though highly likely, the researched confirmation from Chapter 3 formed the basis of the later research. Typically, infographic research tends to compare an infographic with a control group such as the same information in a basic written format (e.g. Lonsdale et al., 2019, Martin et al., 2019; Hughes et al., 2021). This was the first publication to, instead, experimentally compare infographics of varying levels of design principle application, to investigate a relationship between number of applied principles and the effectiveness of the infographic.

Additionally, it was also the first design-based publication to use eye-tracking software to explore the effect of infographic design principle application. It was utilised in this study to gather supporting data to investigate user information location patterns and speed on the infographics tested. Thus, providing useful insights into the ease of information location on the designs, and areas of focus; whether these be on distracting elements, or desirable focus on important information. The eye-tracking data found important supportive findings showing that information was located most efficiently when a high number of principles was applied to an infographic, and the underlying reasons behind this. The technique has been widely utilised in the field of multimedia design to investigate the effect of multimedia principles (Alemdag and Cagiltay, 2018), though much less frequently in the more specific context of information visualisation and infographics. However, it has previously been employed to investigate infographic layout variations (Hossain et al., 2018), and proposed as an appropriate method for examining the efficiency of a visual design (Majooni et al., 2018). These publications use the software to investigate viewing patterns based on layout variation. The conclusions of the study from Chapter 3 further develops the method in this context, endorsing eye-tracking as an effective design methodology to gather supportive data to determine the effectiveness of information design outputs.

Previous publications have presented design principles as a method to improve general infographics, and have utilised both a literature review (e.g. Lonsdale and Lonsdale, 2019), and novel methodology frameworks (e.g. Dunlap and Lowenthal, 2016) to define infographic design principles. More specific publications have also taken place, defining infographic principles in the context of medical infographic (e.g. Hernandez-Sanchez et al., 2021) and public health infographic design (e.g. Stones and Gent, 2015a). The findings from chapter 3 established that the application of research-based design principles, such as these, can improve the effectiveness of infographic design. As shown, the 'good' infographic (that applied 84/84 principles) performed better than both the 'average' (42/84 principles), and 'poor' (1/84 principles) infographic. Though the research used public health infographics as a case study, the effect of infographic design was investigated rather than the content; meaning the results are likely applicable to general infographics no matter the content. These are therefore highly applicable findings given the widespread use of infographics across multiple communication fields. The conclusions of chapter 3 provide evidence that design principles be adhered to optimise the effectiveness of infographics, and in order to maximise this effectiveness they need to be adhered to at a high level. As shown, ‘average’ infographics that applied a middling proportion of design principles were significantly less effective than the ‘good’ infographic that applied a very high proportion. To create the most effective outputs, that are efficient to locate information on and most appealing to users, infographic designers should aim to adherence to a high proportion of principles in the design process. The 84 design principles defined in the literature review of this project are presented as a reliable resource to follow, as the study from Chapter 3 found explicit evidence of the benefit of their use. As stated, these principles were investigated in the context of public health infographics. However, the principles defined in the literature review were not content specific so are applicable to any infographic.

At present, infographics appear to be in widespread use across multiple fields of information dissemination, including: public health, journalism, research publication abstracts, business communication, education, and more. Though the effectiveness of infographics in efficiently communicating complex information is often presented (e.g. Chiu et al., 2015; Ibrahim et al., 2017; Huang et al., 2018a; Thoma et al., 2018; Provvidenza et al., 2019; Egan et al., 2021), proven methods to assure design effectiveness are infrequently explored in these publications. Atenstaedt (2019) has suggested the development of a standardised healthcare infographic templates as a means to ensure they are easily understood. Though this has its limitations, it would require a specific amount of information to fit a template without being overcrowded or too empty of information. Template standardisation would also make infographic outputs very visually similar, the effect this would have on user engagement is unclear and could limit the design evolution of this growing field. The findings of chapter 3 present an adaptable method to achieve effective design outputs; through the careful application of research-based infographic design principles.

6.3.3. Chapter 4/5 methodology impact

In chapter 4, it was acknowledged that the adherence to 84 infographic design principles was a challenging expectation given the lack of design experience present in the target audience of the principles within this research. To address this the principles were condensed in a 3-stage method to allow for easier and more efficient understanding. This method aimed to reduce the number of design principles in the list, whilst still retaining those that were most beneficial. The time constraints of the research also meant that primary data collection had to be rapid, preventing the collection of detailed data on individual principles. So, a methodology had to be created that could meet these aims in an efficient time frame.

The resultant methodology was a 3-stage process that first condensed the principles from 84 to 20, whilst only explicitly removing 26 of the less applicable principles. Stage 1 involved a critical analysis of the principles, removing those that were not realistic for the target audience of the principles to follow, too general to be effectively used, or too subjective to be understood and applied. Stage 2 combined principles using a basic form of exploratory factor analysis, to group principles from different design categories that had parallel meanings. Stage 3 used a survey of successful infographic designs to explore principles that were commonly unapplied, then removing these based on the logic that these principles did not appear important enough to prevent a design from being successful. Also, a second round of basic factor analysis was employed to group similar principles. The multiple rounds of critical analysis and grouping were imperative in condensing the principles from an extensive 84, to a concise 20, whilst retaining those principles that appeared most salient.

This process could be used as a future methodology to condense a number of design principles into the most applicable when considering the context of their use. This may be especially appropriate to large lists of principles derived from detailed literature reviews (e.g. Lonsdale and Lonsdale, 2019), if they are to be used in a practical context. Given the evidence in this thesis of the effectiveness of design principle application in improving information design outputs, this presents an efficient method of rapid summarisation and potential dissemination of design principles across multiple design fields. Other research projects with generous time scales and resources may wish to collect more detailed data on individual principles to allow for statistic factor analysis. However, this method allows for an efficient process for principle condensation. In circumstances where the principles are used as an education resource, the condensation and simplification of complex design principles that this method allows for should be particularly useful. The use of this method may allow such principles to be both easier and more efficient to understand.

Later in Chapter 4, educational motion graphics were developed to address the problem that non-designers may display difficultly following and applying design principles in a written or static form. The motion graphics aimed to educate this target user on how to apply 20 design principles when creating infographics. The impact of the motion graphics was investigated in two distinct stages, the first requiring participants to generate infographics designed by participants before and after accessing the education resource, later comparing the infographics design in both groups.

Due to COVID-19 limitations, a novel and remote design methodology had to be developed to investigate the impact of the motion graphic education process in this first stage. This testing process had to allow the healthcare professional participants to design their own infographics on personal laptops or computers. To address this difficultly, a design software had to be selected that would be both easy to use for non-designer, and freely available. This led to the selection of Google Drawing software, a free open-source online software that can be used to design diagrams and infographics. The aim of this stage of research was a practical investigation into the impact of the education process, looking to generate infographic outputs by the intended user of the motion graphics. Typically, common design generation methodologies that involve the target user, such as a co-design or usability testing approach, create design outputs generated by a designer using the input of the intended user (Martin and Hanington, 2012). Here, however, only the non-designer user was intended to generate the design output, whilst still having access to a design specialist for software advice during the process. This led to the remote research being conducted in two 2-hour sessions over video call. The researcher explained the requirements of the study and relayed instructions on how to use of the software, with screensharing an easy tool to communicate these issues. The designer was present throughout the session but only to address any difficulties with the software. Consequently, each participant generated two infographics, one in the first session with no external input, and the second in a later second session after accessing the educational motion graphics. This novel remote design generation method was coined 'heuristic generative design'. Martin and Hanington (2012) defines 'generative research' as design generation driven by the expression of the user's needs, and 'heuristic evaluation' as the assessment of design outputs based on usability practises. Thus, neither individual definition was appropriate for this method. The process was 'generative' in the sense that design outputs were generated, and 'heuristic' due to the practical process that required the participant to learn and create their own output, using usability principles.

This 'Heuristic generative design' method allowed for the remote creation of infographic design outputs by a non-designer participant. However, it does not need to be limited to non-designers and could be utilised by design research requiring the remote generation of various design outputs. This has the potential to be useful to design research, given the recent uptake of remote working practises that often make design research processes challenging. More specifically, it could also benefit researchers investigating the impact a specific process has on design generation. Such a process may be an education tool, as was investigated here. Most design methodologies that involve the target user does not require this audience to undertake the design process, instead a design specialist typically responds to the requirements established by the user. This methodology, that requires to target user to compete the design process, is valuable in research where the designer is the target audience of the research; a process not commonly addressed in current design research methodologies.

A further contribution to knowledge lies in the definition of a process for developing a effective design teaching tools. The motion graphics that were designed here were highly effective in teaching complex design practices to an audience that had received no previous design training, allowing these users to both understand and apply new knowledge in an efficient time frame. This process is likely repeatable for in other design principle educations programmes in any context. The practicalities of the principles in question should, first, be considered; condensing their number if appropriate using a method such as the one employed in this thesis. They should then be grouped into related design categories to organise the concepts. It is recommended to include 5 principles per video, as was done in this thesis, to ensure the video is short and divides the information into a manageable chunk. The motion graphics development should then follow a user-centred design approach, by developing the resources using multiple stages of usability testing as was done in this thesis. This ensured the resource was addressing the core needs of the intended audience and directed the content at an appropriate level of knowledge, whilst adapting the output where difficulties were identified.

Another vital component of future educational motion graphics should be a simple step-by-step structure, that uses clear visual examples to illustrate the core messages (e.g. individual design principles). Feedback from the users of the motion graphics from chapter 5 commonly highlighted that this allowed them to understand the complex design concepts and apply this knowledge to their own work. Additionally, a complimentary static resource that summarised the content was advantageous to the users. The user feedback was very positive for this summary material, finding is useful to refer back to during the design process to remind them of the content that was covered. Consequently, a complimentary resource that summarises the key points of what was taught in the motion graphic is recommended to maximise learning potential. This motion graphic development process is recommended for the teaching of design practises, and appears particularly advantageous for remote and beginner level design education.

6.3.4. Chapter 4/5 results impact

The improvement analysis, displayed in figure 5.10 (p.207), compared the difference in application frequency for the 20 individual design principles between the infographics designed before and after accessing the education resource. Here, one of the key contributions to knowledge presents as the finding that suggests there is equal importance across all four design categories (layout, colour, type, graphics). All four categories saw a very similar frequency of additional principle application, after the motion graphic education process. This implies that there is not one specific design category that has importance over another, instead, future design principle application processes should take into account all four categories in order to maximise effectiveness.

Previous research has occasionally focused on a singular category when investigating benefits to information design outputs, such as layout variations (e.g. Hossain et al., 2018; Majooni et al., 2018). The findings from this thesis suggest that to maximise the effectiveness of infographics, and other applicable information design formats, all four key information design categories should be considered in research processes aiming to improve or explore the effectiveness of design output. This is not just applicable to research contexts, and any design or improvements process for infographic design should consider design principles covering layout, colour, typography, and graphics. Considering this in the context of the communication of public health information, it is advised that public health infographics designers should apply principles from these four categories.

The analysis also revealed which individual principles were most improved (see figure 5.10 for details). Though this does not identify the most salient principles, as the most important could be those already applied in higher frequency in the initial design stage. Instead, it identifies those principles that were more important in this education process, so those that may have had the greater impact to the improvement in effectiveness to the infographics in this context.

The findings also show that the certain principles are typically applied in a high proportion (67% or above) in the G1 designs prior to the education process. This percentage threshold is based on the International Standards Organisation (ISO) for acceptable comprehension rate in evaluating visual symbols (An and Chan, 2017). Here, it has been adapted to use in this context to evaluate if there are high levels of existing comprehension of design principles in healthcare professionals. The following three principles are: P4 – Noticeable headings, P12 – Appropriate text size, P17 – Avoid decoration (see figure 5.10 for more detail). When researching using healthcare professionals, it appears non-designers possess some existing understanding of good design practices. The discovery that certain design principles are already understood by non-specialists has yet to be acknowledged in design research, and may have helpful implications in future principle definition and teaching.

This could be beneficial as a methodology that could be used to reduce a number of principles that has been established. For example, asking the target audience of any design principles to first create the desired output before any principle education takes place, this could then identify principles that are already used in at least 67% of designs. If future teaching of design principles is required to be condensed further (e.g., in instances where more efficient education processes are required), the removal of these principles would be justified based on these comprehension thresholds. Future design teaching processes may wish to focus on principle education in those that are not already applied above the 67% threshold, concentrating on areas that could benefit most from improvement to create more efficient education resources.

One additional area of importance discovered in the research of these chapters lies in recognition of the needs and difficulties present for healthcare professionals when creating information design outputs. The research with 9 healthcare professionals from this chapter found that every individual had been required to create health-related infographics in the past. Additionally, this demographic was not just being required to create infographics for their work or education practices, but they were being displayed in important public settings such as hospitals, GP practices, medical conferences, and medical schools. They expressed that during their extensive study and work training they have received no teaching on information design practices. This highlights a key problem; that healthcare professionals are absent of support or training on the information design practices they are required to undertake.

After the initial design stage prior to any design training, the healthcare professionals frequently expressed that they were not happy with the infographic they had created. It appears that the healthcare professionals could identify that a design was poor but not which specific features made it so. They were aware that the design choices they had made in their initial infographics were not optimal, but their lack of existing design knowledge meant they did not know how to address this. The educational motion graphics helped them to recognise mistakes in their existing design practices, then, the step-by-step application instructions with examples allowed them to apply the new knowledge in their next designs.

One of the usability testing stages that was employed in the development of the motion graphic resources involved 5 healthcare professionals. Again, it was found that all participants had been required to create infographics for their work or study. Also, the healthcare professionals emphasised that the resources they were using should be as efficient as possible. It was discussed that their working hours are often long or during unsocial hours such as night shifts, meaning that they often have limited free time outside of working hours. To address this need, teaching materials aimed at healthcare professionals need to be efficient and engaging, to maximise learning potential in the limited time available to this demographic.

The performance findings from chapter 4 indicated that the education of non-designers on infographic design principles resulted in meaningful improvements in later infographic design outputs. Experimental comparison of public health infographics designed by a healthcare professional before (G1) and after (G2) accessing the resource found significantly better user performance with the G2 designs. Thus, finding evidence that use of the educational motion graphics significantly improved the effectiveness of infographics created by non-designers. This study found further confirmation of the results in the first study conducted in this project (Chapter 3). In both studies, infographics that applied more design principles resulted in significantly better user performance.

The COVID-19 pandemic required the rapid dissemination of important public health messages, a demand that was apparently addressed through the distribution of infographics. Publication of COVID-19 infographics using social media has been found to result in widespread distribution to both public audiences (Hamaguchi et al., 2020), as well as in clinical environments aimed at healthcare professionals (Chan et al., 2020). Research has shown that when engaged with, infographics have the potential to positively impact COVID-19 behavioural changes, including uptake of vaccines (Crutcher and Seidler, 2021), and mask wearing in public (Egan et al., 2021). Recent research interest in the field of infographics is apparent, yet the effectiveness of the designs that are tested are frequently overlooked (Kemp et al., 2021). The results of this project offer a reliable method to maximise the effectiveness of infographics displaying key healthcare messages, such as COVID-19 information. This being the use of the education resource before the design process of public health infographics, potentially improving the information location speed, memorability and user opinion of these important design outputs.

The distribution of this resource to the target audience is the appropriate next step for future research. Scott et al. (2016) emphasise the need for healthcare professionals to understand and create their own infographics to summarise research papers. Use of the educational motion graphics developed in this project could improve the effectiveness of these outputs, helping such an audience to maximise the accessibility of their findings. The research further contributes to the field of infographic design. So far, experimental research in this field typically compares infographics with another format to investigate their value (e.g. Ebrahimabadi et al., 2019; Lonsdale et al., 2019; Martin et al., 2019; Hughes et al., 2021) or investigates the benefit to information communication in various contexts and measures (e.g. Chiu et al., 2015; Ibrahim et al., 2017; Huang et al., 2018a; Siricharoen and Siricharoen, 2018; Thoma et al., 2018; Lindquist and Ramirez-Zohfeld, 2019; Provvidenza et al., 2019; Egan et al., 2021). Publications have also suggested and defined infographic principles as a practical method to improve the design (Otten et al., 2015; Stones and Gent, 2015a; Lonsdale and Lonsdale, 2019; Hernandez-Sanchez et al., 2021). The findings from chapter 5 broadens the field by applying this established knowledge in a practical context. It explores the consequences of design principle education and practical methods in which this can be achieved to improve the effectiveness outputs of a field (public health) that is reliant on their use.

The aim of the chapter was to develop and test a method of infographic principle education that could be utilised by non-designers, and result in the creation of effective public health infographics. Based on these findings it can be concluded that this aim was successfully addressed. The research from this final chapter presents the first evidence, at time of writing, of design principle education as an effective method to improve public health infographics. It is also the first to explore motion graphics as an education method for improving design practises. The implication of this potentially important research could benefit future public health infographic communication, provided the education resource is successfully distributed. It could improve the ease of use, memorability, and user engagement with this common form of health information communication. Maximising the adherence to key public health messages displayed using infographics possesses the potential to benefit public health behaviour, impacting the prevention of disease and maintenance of human life. Given the reliance on infographics to disseminate COVID-19 information (Chan et al., 2020; Hamaguchi et al., 2020), contribution to this crucial field is relevant to public health and future pandemic impact prevention.

This study also collected the first known evidence, at the time of writing, that motion graphics are a successful education method for teaching complex design practises (e.g.

design principle application) to a non-design audience. This presents an important finding that can be utilised in design practises where non-designers commonly generate design outputs. Examples of design outputs that could also benefit from motion graphic education includes: educational social media graphics, academic visual abstracts, healthcare information design (e.g. patient leaflets), multimedia information presentation (e.g. lecturer/student PowerPoint slides), and academic posters. It is acknowledged that the education of non-designers, on infographic principle application, will not result in the subsequent creation of infographics by this demographic that are higher quality than those generated by experienced information designers. The years of educational and practical design experience frequently exhibited specialist designers will result in higher quality outputs. However, the non-designer audience will continue to generate their own information design outputs regardless of the quality. The dissemination of research-developed education resources, such as the infographic principle motion graphics developed here, could help to maximise the effectiveness of these outputs. Ensuring these designs (e.g., public health infographics) are easier to understand, to remember, and more likely to be engaged with.

The findings may also be applicable to graphic designers. Although they will have both training and experience in the field of design, the broad category that graphic design encompasses means that these designers will have variable experience in the creation of infographics. Depending on the specific field of graphic design, certain fields have more artistic approaches, rather than the pragmatic methods frequently used in information design. If a graphic designer is newly required to create infographics, whether the content be public health related on not, the educational motion graphics may provide a helpful resource to optimise the effectiveness of their outputs. Even information designers with experience creating infographics have potential to benefit from the resource, as the highly variable nature of design makes it difficult to create a perfect output. The education resource is also not constrained to just the improvement of public health content. Though here, the project focused on public health information as a case study, the principles that were defined in the literature review were applicable to all infographics regardless of content. This means there is potential for this research to benefit fields other than just public health information. Any infographics design has the potential to benefit from the adherence to the design principles defined in this thesis.

Meaning subjects where the creation of infographics is common could benefit, especially if typically created by a non-designer.

The research in this thesis focuses on healthcare professionals, but given the general lack of infographic design education available, this resource is applicable to any public health organisation or individual working in the field that are creating infographic outputs. The results from chapter 5 show that this resource has the capacity to improve the effectiveness of infographics, and in the setting of public health this has the potential to benefit the learning and adherence to key health messages.

This also established that user-centred motion graphics are an effective and efficient means of teaching complex design concepts to demographics with limited design experience. The findings from chapter 3 showed that a high level of principle application was required to maximise the effectiveness of public health infographics. Based on the previous threshold values defined in chapter 3 (p.90), a 'good' infographic was one that applied 80% of the principles or above. The average amount of principles applied in the G2 designs was 86.7%, meaning the design principle education process results in acceptable design outputs based on this threshold value, finding further supporting evidence for the effectiveness of the education tool. It is important to note that this was achieved using a demographic that had no formal design training. The efficiency of this teaching material has to be highlighted, given that the materials could be consumed in under 30 minutes (as each of the four motion graphics were under 5 minutes in total length). This was accessed twice by the participants, meaning that the learning time likely took no longer than an hour. The user feedback was comparable with positive opinion on the ease of their use or helpfulness in explaining the design concepts. The proficiency of this teaching tool is exemplified here, with the successful teaching and application of complex information design concepts achieved with an audience with no prior design training in a minimal time frame. This meeting the previously defined needs of the healthcare professionals, stating they would need the teaching process to be efficient. From a practical perspective, a tool such as these could easily be integrated into healthcare professional training given the short time frame required to make a significant improvement to information design outputs.

Additionally, this method has proven to be successful for remote education practices, given that the development, dissemination, and research using the motion graphics was completed solely online. This is particularly useful in current education practices, where a combination of remote and in-person teaching has become commonplace after the covid-19 pandemic. It also allows for the development of effective education programmes appropriate for worldwide distribution, such a Continuous Professional Development (CPD) and online teaching programmes (e.g. LinkedIn Learning).

The support found for the use of motion graphic videos as an effective design education tool for non-designers is potentially important, especially when considered in the context of public health information. It is recommended that an infographic design tool, such as this, be implemented into the education programmes of healthcare professions, either at student level, or professional level (as part of a CPD programme), or both. Integration could also be beneficial in public health organisations, as previously discussed by Stones and Gent (2015) the individuals responsible for creating infographics from these organisations are not often specialist infographic designers. But rather, those with limited design experience tasked with the role. Successful integration into healthcare education and public health organisations has the potential to improve the effectiveness of infographics generated in the field of healthcare and public health.

Summary of the contributions to knowledge established in this thesis:

1. **Chapter 2** – The literature review of research-based publications in fields related to infographic design, involving the collection and distillation of 84 design principles from various related sources.
2. **Chapter 3** – The finding that a high level of principle application is required to maximise the effectiveness of infographics (displaying public health information), as appose to average or low level.
3. **Chapter 3** – The application of the 84 design principles established in the literature review resulted in significant improvement in user (general public) performance, and opinion ratings.
4. **Chapter 3** – Design principle application is an effective technique to maximise the effectiveness of public health infographics.

5. **Chapter 4** – Identifying a method to condense a large number of design principles into the most applicable, in an efficient time frame.
6. **Chapter 4** – Identifying a research methodology that allows remote generation of infographic design outputs using open access online software, defined as 'generative heuristic design'
7. **Chapter 4** – Establishing that healthcare professionals are required to create infographics for study/work practices that are publicly displayed, and understanding the needs of this demographic in settings where they are required to generate these outputs.
8. **Chapter 5** – Developing a user-centred motion graphic tool to educate healthcare professionals on infographic design principles, that allows the generation of significantly better infographic design outputs by this demographic.
9. **Chapter 5** – Identifying that bespoke motion graphics are a successful education method to teach complex design practises to users with limited prior experience.
10. **Chapter 5** – Establishing a process that can be used to create these successful design education materials.
11. **Chapter 5** – Finding that each category of design (layout, colour, type, graphics) appears to be of equal importance, and the identification of design principles that were most improved.

6.4. Limitations of the research

The first limitation acknowledged in the project was recognised in the research methodology of the experimental study in chapter 3. The data collection only asked 3 questions in order to investigate the function of the infographics, testing both information location efficiency and memorability of the designs. It was hypothesised that the infographic designs that applied more design principles (e.g. the 'good' infographic) would be more memorable due to the less distracting designs and optimisation of information comprehension. The 'good' infographic was found not to be significantly more memorable than the 'average' or 'poor' designs, when measuring both short and long-term memorability. This was addressed in the subsequent research completed in chapter 5; instead of asking just 3 information location task questions, 7 were asked with the aim to cover more of the infographics tested. This would also investigate information memorability in greater detail as, consequently, more questions were asked in the information recall section. Additionally, when testing for memorability, an open question was asked directly to the participants with emphasis that they should not guess and state they did not know the answer if they could not remember. This was to help reduce the potential effect of guessing. Significant improvement in short-term memorability were found in infographics designed after accessing a design principle education resource in chapter 5. This suggests that the non-significant memorability results observed in chapter 3 may have been influenced by the imperfect methodology.

Another of the limitations of the project is in the method utilised in the project to reduce the number of principles from 84 to 20. A problem was recognised, finding that adherence to 84 design principles is unrealistic for an individual from a non-design background. Consequently, the principles were condensed from 84 to 20 using a 3-stage method. First, by removing those considered too subjective or unrealistic, then grouping related principles, and finally removing those not applied to high quality existing designs. It is acknowledged, however, that the process retains some subjectivity, as the process was undertaken by the researcher alone. Ideally, the effectiveness of each individual principle would be explored, statistically comparing infographics that did or did not apply a principle to understand if it made a meaningful impact to user performance measures. This would allow for identification of the most salient principles. Unfortunately, given that 84 principles were defined in the literature review this level of research collection was impossible in the timescale of the project. Manual reduction of these principles based only on researcher opinion may have resulted in inaccurate outcomes. Instead, the 3-stage reduction methodology was used as a more reliable method to recognise the important principles in a timeframe realistic to the project.

A final limitation of the project lies in the applicability of the findings. The developed education resource was found to improve the effectiveness of public health infographic design created by a non-design user. This finds an important method for optimising public health infographic design. However, the motion graphics from the education resource are publicly available, but hosted on YouTube with minimal engagement. The supplementary pdf that summarises the motion graphics is currently not publicly available. In order for these resources to have any potential benefit to the design of public health infographics they need to be both publicly available, and meaningfully engaged with. It is also recognised that the final infographic outputs created after accessing the education resource still have scope for improvement; none of the outputs applied all 20 of the design principles, though many were close. However, given the lack of design training and experience of the creators, the infographic outputs they designed appear to be of satisfactory quality. Though it is understood that an information designer with years of design education and experience is likely to produce more effective designs.

6.5. Future research

The first aim of future research should be to maximise the distribution of the motion graphic education resource developed during this project. To achieve this, it is proposed that a publicly available website is developed that can host the motion graphics and pdf summary. This would allow this education resource to be easily accessed and shared by the envisioned non-designer target audience. Dissemination of the resource through social media platforms may also be beneficial, given the effectiveness of this method in the distribution of public health infographics (Chan et al., 2020; Hamaguchi et al., 2020). As previously discussed, the motion graphics are applicable to all infographics no matter the content. Free widespread access to the resource, as shown by the findings of the final research study, could maximise the effectiveness of any infographic generated by a non-designer audience. Another means of dissemination could be the integration of this tool into the education programmes of healthcare professions, aiming to make this audience both aware of the benefit of effective information design, and provide the skillset to allow them to maximise the effectiveness of their own design outputs.

Future research may look to explore alternative applications for the finding that bespoke educational motion graphics are an effective education tool for a non-designer audience. Fields where non-designers frequently generate information designs to display important and complex information are particularly applicable. As such, two such appropriate examples include academic posters and academic visual abstracts. These fields typically require a non-designer (e.g. academics across various subjects) to design a poster or infographic that visually summarises the key findings of their research, aiming to make their research accessible and engaging to a broader audience. Recent research in the success of visual abstracts on research engagement (e.g. Huang et al., 2018a; Thoma et al., 2018) has also popularised this practice. However, preliminary observation appears to reveal that these outputs are frequently poorly designed with dated design elements, particularly visible in academic posters. Thus far, the effectiveness of these abstract infographics has not been considered in current research. Though currently unresearched, it is hypothesised that bespoke educational motion graphics could teach academics how to apply design principles. Resulting in more effective outputs that have the potential to maximise the ease of use, knowledge acquisition, and engagement with their research findings, as based on the findings from the final study of this project.

The findings of this thesis may also benefit the field of infographic research itself. Infographics that are developed and tested in this discipline are frequently lacking in quality and disregard important design principles (e.g. Stonbraker et al., 2019; Hamaguchi et al., 2020; Lunn et al., 2021). By improving the effectiveness of the infographics researchers choose to experimentally test, as this project has shown, could result in significant differences in the results (e.g. when comparing infographics with control groups or other information formats). It is recommended that infographic design researchers adhere to design principles, such as those defined in this project, to accurately test the true potential of this form of information visualisation.

Finally, future research may want to investigate the real-world application of improving the effectiveness of public health infographics. Infographic information dissemination has already shown to result in positive behavioural changes in relation to COVID-19 safety practises (Crutcher and Seidler, 2021; Egan et al., 2021; Lunn et al., 2021). Optimisation of the infographics that display essential public health information has the potential to improve information location speed, memorability, and user opinion of this material. So far, the impact this could have on adherence to public health messages is speculative, though consideration of the current research would suggest this could be beneficial. Consequently, future research is encouraged to explore if the improving the effectiveness of public health infographics also produces a meaningful benefit to public health behaviours. COVID-19 infographics presents as a potential research case study, infographics displaying this information could be re-designed to apply the principles from the motion graphics. Later investigating if public education using these more effective infographics results higher vaccine booster uptake, or adherence to social distancing measures, when compared to the less effective original design. Though the pressures of the current pandemic appear to have eased recently, the communication of public health messages will likely always be relevant, so research in communicating future health messages remains appropriate. Consequently, the future application of the project findings proposes important potential benefits to subsequent public health communication.

6.6. Conclusion

The core aim of this project was to identify a tool to improve the effectiveness of public health infographic design. As established, infographics have already been shown as an accessible and efficient communication tool that are frequently utilised to display public health information. The field's reliance on this communication method, as well as the understanding that they were regularly produced by a non-designer audience, justified to the need for the projects aim.

Design principles were recognised as a means to improve infographics, so were carefully reviewed, and defined in an extensive literature review. This required the interpretation and summarisation of a large body of research-based publications that were appropriate to the subject. Resulting in the creation of a detailed summary of 84 infographic design principles. A valuable resource for infographic designers that can be used to inform design decisions and improve the effectiveness of their outputs. The applicability of these principles was later explored in the context of public health infographics, finding the higher the number of principles applied the more effective the graphic design output. Consequently, obtaining evidence that optimal infographic design required the application of a high level of design principles. The results presented a method to achieve effective design outputs; through the careful application of the design principles defined in the literature review.

In response, an education resource was developed to allow these principles to be accessible to a non-designer audience; thus, allowing this target group to independently create more effective outputs. First, the number of principles were condensed to allow them to be understood by the target audience, then a series of bespoke motion graphic videos were developed to successfully educate the user on their application. This established the design needs of healthcare professionals, and addressed them in an iterative user-centred design process. Experimental research confirmed the advantage of this resource, finding that design principle education using these motion graphics resulted in the design of significantly more effective public health infographics by healthcare professionals. The developed motion graphic education resource is an original and potentially important contribution to the field of infographic design. As shown, it can help maximise the effectiveness of infographics created by a non-designer audience. This also established a method of effective design education tool development, and in the context of public health, encouraged the intergration of such a tool into healthcare student and professional educational settings.

If successfully integrated, this tool could benefit future infographic communication by allowing non-designers to independently generate their own effective infographics. Positive implications of this in context include more effective infographics displaying key public health messages, so potentially benefitting the prevention of future disease and prolonging of human life. The findings of this project have the potential to benefit future public health communication, and contributes important knowledge to this ever-expanding field.

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8. Appendix

OGNITIVE PRINCIPLES	
Signalling	Highlight the most importance information using visual cues to optimise user learning potential (Mayer, 2009).
Chunking	Organise related information into meaningful 'chunks' to increase chance of the information being retained and reduce cognitive load (Miller, 1956; Mayer, 2009; Patterson et al., 2014; Tetlan & Marschale, 2016). These should be defined using visual tools such as white space, colour and application of the gestalt principles (Patterson et al., 2014).
Spatial Contiguity Principle	User learning is optimised when images and the corresponding text are placed in close proximity rather than far apart (Mayer, 2009).
Cognitive overload	Prevent cognitive overload by preventing the display of too much information at once. This is applicable to both text and visual information meaning a design should be simple and clear (Mayer & Moreno, 2003; Patterson et al., 2014).
Unnecessary cues	Remove unnecessary visual cues to allow a user to focus their attention on the most important information (Patterson et al., 2014).
Exogenous attention	Exogenous attention is the unconscious attraction to a visual stimulus. Attract a user's attention to the most important areas of an infographic using visual cues such as colour (Patterson et al., 2014).
Endogenous attention	Endogenous attention is defined as the voluntary attention of a user towards a stimulus. Information should be organised using visible cues that direct a user's attention; such as designing an arrow that leads to an area of important information. (Patterson et al., 2014).
Familiar visual representation	By creating visuals that are similar to universally learned information, a user can better understand and memorise information as it is connected to their prior knowledge. An example being using familiar icons, such as male and female toilet signs. (Burkhard & Meier, 2005; Patterson et al., 2014).
Consider cognition	Understand user and tailor design based on the application of the information with consideration of cognitive processing (Patterson et al., 2014).
Create hierarchy	The creation of hierarchy within visual information designs optimise processing; leading to optimised learning (Tetlan & Marschale, 2016).
Consistency	Common or repeated information should be consistently presented the same way, in terms of placement and appearance to allow the under to locate the information quickly (Bettman et al., 1986).
Visible choice	Limit the number of visual choices available to streamline a design and the reading order, as too many choices difficultly (Hick, 1952).
Align information	Align information visualisation design with user thought patterns and task demands, through careful research into user perception (Padilla et al., 2018).

YPEFACE PRINCIPLES	
Number of typefaces	Typeface families should be limited to 2 or 3 in a single design (infographic) (e.g. Saltz, 2009; Babish, 2017; Murray et al. 2017).
Complimentary typefaces	If multiple typefaces are chosen they should be complimentary but distinctly different from one another to allow them to be distinguishable (Saltz, 2009).
Simple typeface	A simple typeface should be chosen that is simple that does not include design elements that might draw unnecessary attention or reduce the legibility of the information (Black, 1990; Hartley, 1994; Hartley, 2004).
Large X-height	Use a typeface with an appropriately large x-height to increase legibility when text is displayed smaller (Poulton, 1972; Pušnika et al., 2016a).
Capitalised letters	Avoid using uppercase type for sentences as they are read slower (Tinker & Paterson 1928; 1942; Tinker, 1955)
Screen designed type	Use a typeface designed for screens when displaying information in that format, such as Verdana (Bernard et al., 2003; Chaparro et al., 2010; Hojjati & Maniandy, 2014).
Sans-serif	Use a sans serif typeface onscreen as it is preferred, and evidence exists suggesting it is more legible that serif typefaces (Jospehson, 2008; Chaparro et al., 2010; Banerjee et al., 2011; Hojjati & Maniandy, 2014).
9-12 pt Type size	Use a type size between 9-12 pt for the body of text (Tinker, 1965; Bernand et al., 2003; Beymer et al., 2008; Lonsdale, 2014).
55-70 character line length	Use a moderate line length of roughly 55-70 characters per line when displaying block text information to optimise reading (Spencer, 1969; Dyson & Haselgrove, 2001; Ling & Schaik, 2006; Lonsdale, 2014).
Left text justification	Justify text to the left to optimise legibility of online text (Ling and Schaik; 2007).
1.5-2 line spacing	Use line spacing of 1.5 or 2 to optimise the legibility in a block of text (Ling and Schaik; 2007).
Clear text style	Display text in a simple, uncluttered style to prioritise text readability (Bernard, 2003; Amdur, 2007)

GESTALT PRINCIPLES	
Proximity	Place related objects (e.g. image and explanatory text) closer together to allow a user to interpret them as being grouped
Similarity	Make objects more visually similar if they are related. This can be done by matching: colour, shape, size, value, etc; colour has the greatest priority.
Simplicity	Reduce a user's cognitive load when reading infographics to make them both easier to understand and more accessible (Mayer, 2009). This can be done by keeping the design simple and reducing unnecessary visual clutter.
Enclosure	Information can be shown to be related by enclosing it using an outline or blocks of colour. This helps to organise and define hierarchy.
Continuity	Once a user's eye is following a path they will continue to follow it until reaching another object, even if the shape or line ends. This can be utilised to lead a user through the intended reading direction of an infographic by using arrows and lines between one section to the next.
Figure/foreground	The human brain processes contrasting imagery as being in either the foreground or background, with the foreground being of greater importance. Create enough contrast between foreground and background elements to optimise visual legibility.
Symmetry	Symmetry is visually appealing to a user and objects that are symmetrically aligned can also be interpreted as being related. If a design is largely symmetrical, adding an asymmetrical element can focus a user's attention on it.
Focal point	Ensure the design has a clear focal point(s) to emphasise the information of highest importance. Colour, size and shape can be varied to create a focal point.
Connectedness	Information or data points can be connected using elements, such as direct lines or frames, between areas of visual information. Use arrows or lines to connect related data points.

LAYOUT PRINCIPLES	
Colour dominance	Use a highly saturated colour for information of greatest importance, this has greater ratings of importance than variations in hue of colour value (Puhalla, 2008). Highly saturated (darker) colour is most dominant (Puhalla, 2008).
Colour palette contrast	Ensure contrast is high when colour is applied on infographics (e.g. between background and colour, or between colours). This makes dominance clearer (Puhalla, 2008).
Warm colour dominance	Warm colours have dominance over cooler colours, where warm colours attract greater attention (Jacobs & Suess, 1975; Mehta & Zhu, 2009).
Bold attracts attention	Use varying type weight to attract attention and create dominance, where bold text attracts more attention than regular text (Pelli et al., 2006; Lonsdale, 2014; Macaya & Perea, 2014).
Type weight contrast	Ensure that contrast in weight is noticeable between a regular and bold text (Lonsdale, 2014).
Bold text limitation	Due to the attention-grabbing nature of bold text reserve it for specific words and headings, instead of entire sentences (Lonsdale, 2014).
Dominant headings	Use headings to effectively organise information and make information easier to find, they should be one of the most dominant elements of the infographic (Hyönä & Lorch, 2004; Kools et al., 2008; Jin, 2013).
Define headings	Use variation in type weight to establish a heading or title, with larger text being interpreted as having greater dominance (Williams and Spyridakis, 1992; Lonsdale, 2014).
Make headings larger	Text size is the most powerful cue to signify headings hierarchical position. Ensure a heading is roughly 20% larger than the body of text, to ensure the size difference is obvious (Williams and Spyridakis, 1992).
Heading parameter limit	Define headings by a limited number of parameters (e.g. size and weight), as they are recognised slower when defined by too many (Williams and Spyridakis, 1992).
Layout narrative	Layout of infographics should be clear and structured to create an understandable narrative with an obvious order to the information (Murray et al., 2017).
Zig-zag structure	Display infographic information in a zig-zag structure to mimic the natural reading pattern of the English language and optimise comprehension (Majooni et al., 2018).
Reading pattern	Make sure information is displayed in a left-to-right, top-to-bottom order structure to mimic the natural reading pattern of the English language and optimise comprehension (Majooni et al., 2018).
Layout grids	Present the infographics in a clear grid-based format as this makes eye movements more predictable and allows a designer to control the order of information consumption (Stones & Gent, 2015; Majooni et al., 2018).
Branding consistency	Create consistency between infographics with coherent design elements if representing single organisation or brand (Zhang, 2017).

Appendix 1. A display of the principles that were defined in the literature review through the consultation of primary literature.

COLOUR PRINCIPLES

Colour preference	Avoid using colour based on personal preference, but instead to best communicate the information and support the purpose of the infographic (Conley, 2017).
Colour palette limitation	Limit your colour palette to 2 or 3 hues to reduce visual clutter, variations in chroma and value suitable if necessary (Stone, 2006).
Colour signalling	Utilise colour to attract attention and emphasise the most important information (Schaie & Heiss, 1964; Farley & Grant, 1976; Schindler, 1986; Wichmann et al., 2002; Jamet, 2014).
Colour memory	Apply colour to areas of information you want the user to remember (Wichmann et al., 2002; Spence et al., 2006; Kim, 2010; Dzulkifli & Mustafar, 2013).
Colour coding	Colour coding can be used to group information into chunks, that allow for easier comprehension and recall (Dwyer & Moore, 1991; Keller et al., 2006; Mayer, 2009; Ozcelik et al., 2009; Ozcelik et al. 2010; Jamet, 2014; Richter et al., 2016). Show related information is connected by using the same colour to display it (Worley & Moore, 1999; Mautone & Mayer, 2001; Mayer, 2009).
High background/ text contrast	Make sure to use background and text colours with high contrast in order to maximise information legibility (Galitz, 2007; Ling & Schaik, 2002; Moore et al. (2005; Mackiewicz, 2009).
Black text, white background	Use black text on white background, over white on black, to increase legibility (Hall & Hanna, 2004; Buchner & Baumgarter, 2007).
Colour theory	Certain colours can have an effect on a user's emotional response to information, so take this into account when designing infographics. (Jacobs & Suess, 1975). For example, the cross-cultural belief that black and grey are negative while white, blue and green are positive colours (Adams & Osgood, 1973; Madden et al., 2000).
Colour legibility	Ensure applied colours obviously different to make differences in colour clear and well defined (Patterson et al., 2014).
Warm colours to highlight	Use warmer colours to highlight important information as it has the ability to increase attention, over that of cool colours (Birren, 1978; Mehta & Zhu, 2009; Kuhbandner et al., 2015).
Cool colours to relax	Use cooler colours, such as blue, when wanting to relax users or for larger bodies of text (Bonnardel et al., 2011; Kuhbandner et al., 2015).
Associative colour	Consider common associations of a colour and utilise this, when appropriate, to link new information to prior information (Elliot & Maier, 2014; Olurinola & Tayo, 2015).
Careful use of red	Red is commonly associated with higher risk and can elicit increased levels of anxiety, use carefully to increase user vigilance for information in this colour (Friedman & Föster, 2002; Koch et al., 2008).
Colour in context	Avoid complex backgrounConsider what a colour may mean in content of the infographic information (Elliot & Maier, 2013; Conley, 2017), as well as the meaning of a colour, or combination of colours, to a culture (Vanka & Klein, 1995; Madden et al., 2000).
Complex backgrounds	Avoid distracting backgrounds such as gradients (Lonsdale & Lonsdale, 2019).

GRAPHICS (ILLUSTRATION) PRINCIPLES

Content consideration	Visual elements should be consistent with the function, content and key message of the infographic, and determined early on in the design process (Lonsdale & Lonsdale, 2019).
Simple graphics	Use strong, single graphic and graphs over complex ones to maximise user comprehension of the imagery (Houts et al., 2006; Zikmund-Fisher et al., 2008; cited in Stones & Gent, 2015; Mollerup, 2015).
Remove "chart junk"	Infographic illustration should exist with purpose, to explain and aid in the comprehension of written information (Dunlap & Lowenthal, 2016). Visual embellishment should be removed to avoid unnecessary distraction, it should only be used to provide context to information (Mayer, 2009; Patterson et al., 2014; Dunlap & Lowenthal, 2016; Lonsdale & Lonsdale, 2019).
Original graphics	Create original illustration, instead of applying other designer's images, to avoid unconnected or distracting imagery (Arslan & Toy, 2015).
Graphic order	Use elements, such as lines and arrows, to create a clear narrative order (Graham, 2008; Ali & Pebbles, 2013; Murray et al., 2017; Gkogka, 2018).
Style variation limitation	Limit the types of graphic utilised to prevent overwhelming the user (Stones & Gent, 2015).
Pictograms increase comprehension	Use pictograms (over cartoons or basic shapes) if an objective tone is required (Stones & Gent, 2015), or to increase accessibility and comprehension in lower-literacy level users is key (Mansoor & Dowse, 2003; Dowse & Elhers, 2005; Kripalani et al. 2007; Park et al., 2016).
Icon backgrounds	A background can be applied to an icon to emphasise it (McCready, 2016).
Graphic consistency	Ensure there is a consistent style across the graphics of an infographic (McCready, 2016).
Proportional icons	Ensure icon sizes are proportional to create visual balance (McCready, 2016).
Representative graphics	Ensure that graphics are clearly representative of the information they are visualising (Tijus et al., 2007).
Graphic captions	Ensure graphic (pictograms) are accompanied by an explanatory caption to ensure intended interpretation (Choi, 2011).

GRAPHICS (GRAPHS) PRINCIPLES

Avoid graph backgrounds	Avoid complex pictorial backgrounds on graphs as they can reduce performance accuracy (Gillan & Richman, 1994).
Graph over-information avoidance	Avoid trying to include too much information in a single graph, where multiple graphs may be more appropriate and easier to understand (Gelman & Unwin, 2013).
Pictographs	Pictographs are useful for displaying data to users with lower literacy abilities, they are easiest to understand (Hildon et al., 2012).
High graph colour contrast	Make sure colour contrast between variables is strong, with the important statistic emphasised (Stones & Gent, 2015).
Bar charts	Use simple bar charts to clearly display information (Stones & Gent, 2015).
Avoid stacked bars	Performance is worse when using a stacked bar charts, so avoid their use (Cleveland & McGill, 1984).
Pie charts for percentages	Pie charts are useful to display simple percentage data, but avoid for more complex data where accuracy is required (Spence, 2005; Hawley et al., 2008).
Pie chart labelling	Clear labelling of data values is important in a pie chart because it is hard to discern accurate data values from estimated area (Stones & Gent, 2015).

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Appendix 1 (cont.). A display of the principles that were defined in the literature review through the consultation of primary literature.

Note: Only include the BLACK text on your infographic.

Title: Heart attack awareness

Heading 1: Symptoms of a heart attack

- Chest pain or tightness
- Shortness of breath
- Feeling weak or lightheaded
- Feeling nauseous
- Overwhelming feeling of anxiety

IMPORTANT: Symptoms of a heart attack differ, and the pain can often be mild and be mistaken for indigestion. The combination of symptoms is important in diagnosing a heart attack, not the severity of the chest pain.

Heading 2: If you suspect a heart attack

1. Call 999 immediately and ask for an ambulance.
2. Whilst waiting for an ambulance, chew and swallow an aspirin to thin the blood.
3. Sit down and try to remain calm.
4. Begin CPR if the person is not breathing or you cannot find a pulse.

Heading 3: What is a heart attack?

A heart attack (or myocardial infarction) is a medical emergency that occurs when the flow of blood to the heart is blocked. This is usually caused by coronary heart disease where the coronary arteries are narrowed by a build-up of fatty deposits. One of these deposits can break off and form a blood clot that causes the heart muscle to be starved of blood and oxygen.

Heading 4: Reducing the risk

You can reduce your risk of heart disease by living a healthier lifestyle, taking steps such as:
- A healthy diet
- Being physically active
- Maintaining a healthy weight
- Not smoking
- Reducing alcohol intake

Heading 5: Heart disease statistics

Graph 1: UK leading causes of death (2019)

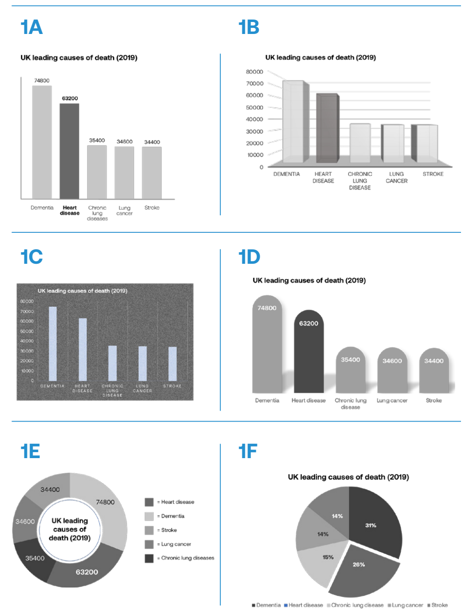
Heart disease: 63200
Dementia: 74800
Chronic lung diseases: 35400
Lung cancer: 34600
Stroke: 34400

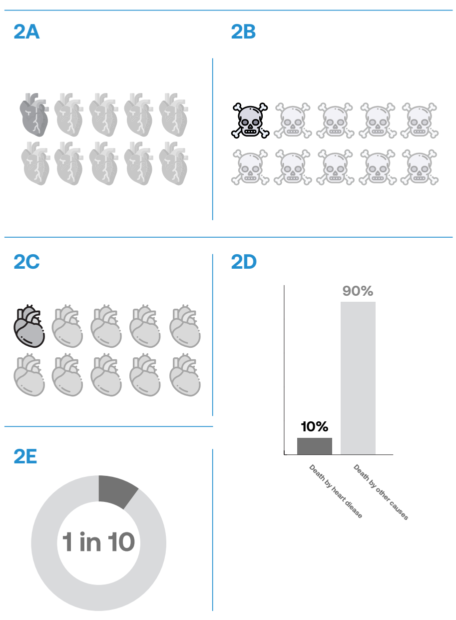
Graph 2:
1 in 10 people die from heart disease in the UK

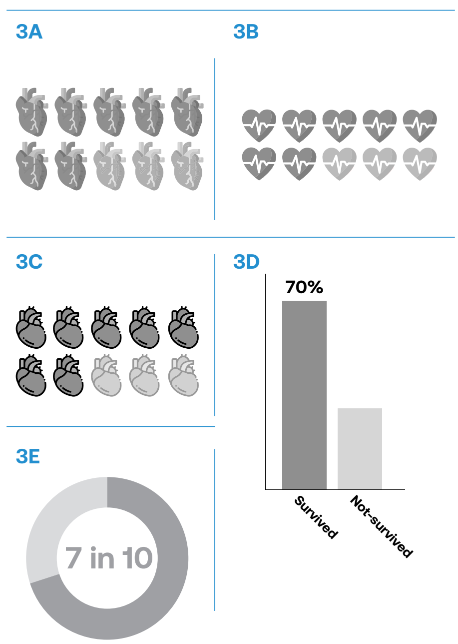
Graph 3:
7 out of 10 survival rate for heart attacks in the UK

All of these graphs display the same information. You must pick 1 to display the stats decribed in 'GRAPH 1'. Once you have selected a style open the graph folder you were sent and select a colour variation.

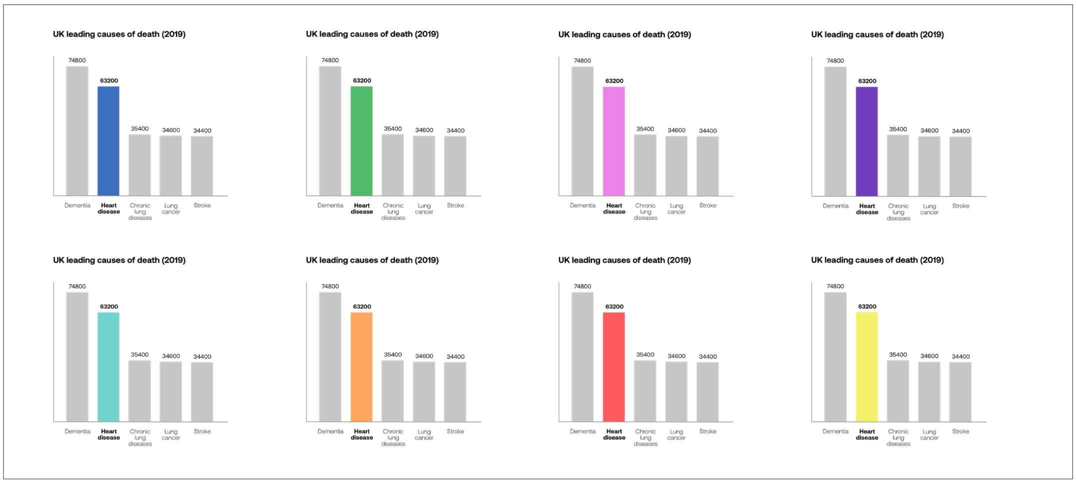
If you would like to use a custom colour please ask the researcher and they will make it for you.







Appendix 2. The information given to the participants that was used to create the infographic they designed (in stage 1 of chapter 5).



Appendix 3. Examples of the colour variations available for each graph displayed in appendix 1, this displays variations for the 1A graph. Each graph had all 8 colour variations available, as well as the option for a specific colour.