Infographics Research:

A literature review of empirical studies on attention, comprehension, recall, adherance and appeal.

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**Abstract**

This literature review is a collation of research methods and findings from academic papers that report on empirical research concerning the impact of infographics on their readers. Research is taken from a range of disciplines including journalism, risk communication and psychology and focuses on 5 key areas: attention, comprehension, recall and adherence (behavioural change) and appeal. This work highlights the scarcity of robust evidence in certain aspects of infographic design despite the large amounts of infographics published and shared every day. Whilst there is much research focusing on say, familiar graph types and comprehension, there is less research available focusing on embellished infographics that are visible in the contemporary press and commissioned by organisations. In terms of attention, there is conflicting evidence concerning whether they can gain initial attention and this seems highly dependent on the surrounding context and the size of the graphic. The visual display of data through bar and line graphs have been shown to be quicker for understanding trends and relationships than text only or purely numerical data though certain aspects of infographic design also impact upon comprehension, such as location of legends and arrangement of icons. There are still comprehension difficulties for significant numbers of the general population when looking at even basic chart formats such as pie charts, despite these being a common feature of infographics. Embellished infographics have been shown to impact positively on recall though few studies of scale and scope exist. There are few studies examining adherence and infographics though use of graphics and pictographs in particular have been shown to aid decision making. Generally embellishments have been found to be more appealing than plain graphs, these do not always aid comprehension. The paper’s contributions are in highlighting methodological problems, such as using non-typical readers such as students, and identifying gaps in the research such as understanding more about the use of embellishment and qualitative humanities based approaches.

**1. Introduction**

Given the growing number of infographics in the public domain it is important that any organisation understands the case for using infographics as a tool for communication with the general public and understands principles of best design practice in the area. In 2002 Coleman & Thorson avoided the use of infographics in their research due to ‘mixed’ results for understanding and recall. Over 10 years later are we in a better position to make a case for their usage and for optimising their design for both appeal and usability? The purpose of this review is to aid designers, organisations and academics by furthering their understanding of infographic effectiveness. This paper is based on early work on a larger research project with a public health organisation that required a firm understanding of the evidence base for using infographics with a non-specialist audience. It will also aid academics and organisations in identifying gaps in the research base so that more systematic research can take place. If “it’s not enough that graphs are merely technically correct in presenting relevant information” (Shah, Meyer & Hegarty, 1999, p.691) then what other aspects of infographic design are important and how are we evaluating them?

The focus on empirical work rather than a broader literature search has created a necessarily narrow set of literature. There are many guidebooks related to infographic design (Few, 2004; Tufte & Graves-Morris 1983, Cairo, 2012) where recommendations are made based primarily on designer’s and statistician’s tacit knowledge gained through practical experience. This is not to say this work is not valid. However we do require empirical knowledge when an evidence base is sought or to resolve certain issues that cannot be agreed upon such as the on-going debate concerning embellishments or ‘chart junk’. It is also important to make the findings of empirical studies available to a wider audience. Many designers might be unaware of the relevant research findings residing in specialist psychology journals and thus it’s important to review and allow research in different disciplines to converge. It is also important to acknowledge that there may also be very valuable evaluative and empirical work in organisations outside of academia that is not published or accessible.

By far the largest set of evidence based studies is in the field of health-based risk communication where infographics, and in particular icon arrays (or array tables) have been in use for many years. Given the serious implications (in some cases of life or death) of decision making in this area, it is not surprising that rigorous research is necessary. Journalism is also an area where infographic research has been carried out though not as intensively. In addition more abstract studies that focus on form rather than content have also been included here.

The goals of this paper are to:

1. Provide a summary and dicussion of findings on how the addition of infographics (or standard graph types within them) affects attention, comprehension, recall, adherence and appeal.
2. Identify areas where more research is needed;
3. Highlight methodological challenges and weaknesses in infographic research

**1.1 Definitions and Scope of the Study**

Spiegelhalter et al (2011) describes an infographic as a “graphical representations of data intended for a nontechnical audience”. There are many terms used to define the visual presentation of data: infographics, data visualization, information visualisation, knowledge visualisation, charts & graphs or graphical presentation amongst others. The scope of this review does not include big data computer visualisations designed for exploratory purposes (though there is some burgeoning empirical research in this area) and focuses instead on the simplification of quantitative data for the lay audience - this includes graph and chart design principles, use of pictograms in icon arrays and methods of presenting proportions to help relay a message, as well as the study of more contemporary and ‘popular’ embellished infographics.

Holsanova et al (2009) state that “An information graphic usually consists of (a) a text of various complexity (key words, phrases, sentences, text paragraphs), (b) pictures on various levels of detail (abstract or naturalistic) and (c) graphical means (arrows, movement lines, zoom boxes, highlighting” . Given their myriad parts attempting to review the effectiveness of them as a whole is challenging and so this paper focuses on the picture element part, that is, the visual element that contains the data or the visual elements that immediately surrounds it.

The systematic study by Borkin et al (2013) reviewed 1721 infographics from visual.ly.com and found the following graphic pictorial /data elements within them: bars graphs, line graphs, points, areas, circles, trees and networks and thus these provide the focal point for this study. Other elements found within them mentioned by Borkin et al (2013) include tables, diagrams, and maps which are omitted from this review either due to their lack of pictorial elements (tables), lack of quantitative data (diagrams) or their multivariate and location-based nature (the combination of locational and numerical data found in maps). This study also focuses on static rather than animated or interactive infographics to again, limit the number of variables to a manageable size. It also focuses on adult learning rather than children’s learning to acknowledge the pervasiveness of the format in the media away from school text books. As Shah & Hoeffner (2002) acknowledge in their review, this study is likely only to consist of a representative sample rather than a collation of all graph and infographic research from every discipline.

**1.2 Methodology**

The following databases were searched (Design and Applied Arts Index, Web of Science, Scopus) as well as the Google Scholar Search Engine. Relevant papers were also taken and inspected from reference lists. The following search terms were used to initially identify publications: ‘infographics’, ‘information graphics’, ‘graph design’, ‘chart design’ ‘graphical presentation’ and ‘visualisation’. Further keywords were employed in reaction to cited papers in order to extend the search.

The criteria for inclusion in the review were are follows: papers that consisted of empirical data about adult-user perception and performance of graphical data; empirical data could be used referring to a range of disciplines or papers that employed comparative elements. The date range was taken from the last 30 years to include earlier papers on graph design. Exclusions applied to papers concerning big data visualisations used for exploratory purposes with specialist users or papers that referred to dynamic or interactive visuallisations. Papers were included that employed comparative studies of either graphical information vs text/table or different presentation techniques of different data.

**1.3 Structure**

The following review follows the structure employed by Houts et al (2007)’s influential literature review about the use of pictures in healthcare materials, based upon the information processing model by McGuire (1999). They divide their review into the useful structure based on 4 of McGuire’s ‘output variables’ - gaining attention, improving comprehension, improving recall and adherence (behavioural change). This structure also mirrors well a broader set of ‘purposes’ of text illustrations by Levie and Lentz (1984). A fifth output variable is included in this study, referred to as ‘liking’ by McGuire (1999) and named ‘appeal’ here. This addition reflects the growing interest in ‘sharing’ infographics over social media and recognising aesthetic appeal as holding some possible cognitive value (Moere & Purchase, 2011; Hullman 2011).

**2. Gaining Attention?**

One of the initial potential functions of any image within a multimodal document is to attract the reader’s attention (Houts et al, 2007, Levie & Lentz, 1984, Spiegelhalter et al, 2011). Visual attention is detemined by a number of variables within the object representation including its shape, colour, size (Yantis & Gibson, 1994). It is important to note that visual attention is also relative to the surrounding context of the infographic. There are two types of possible attention types (Levie & Lentz, 1984) - attention to the graphic itself and attention within the graphic. Methods employed to measure attention of both types include asking participants where they looked first in a document (Pasternak & Utt, 1990) with later studies involving eyetracking technologies (Holmqvist & Wartenberg, 2005; Renshaw et al, 2004; Smerecnik, 2010, Li & Moacdieh, 2014). The latter method has analysed a range of variables including viewing time, number of eye fixations, pupil diameter and eye fixation durations. There is mostly agreement that, in complex information processing (such as reading or picture viewing), the link between eye movement and attention is strong (Rayner, 1998).

**2.1 Attention to the infographic**

Pasternak & Utt (1990) found, in reference to newspaper infographics that readers tended to look at the infographics first but only if it was a dominant graphic. They compared attention to two infographics and 70% of participants viewed the dominant infographic first before reading the story. Their reasons for looking at the graphic given related more to issues of content (e.g. it would enable them to understand the story more) whereas some issues of design were raised - e.g. simplicity. Their recommendations for design are to make the chart *look* easy and to draw attention to the chart using white space. These claims however do not stem directly from their empirical work and more work is needed to ascertain qualities of visual dominance versus content.

Holmqvist & Wartenberg (2005) found, in an experiment with 26 users, that infographics within news stories achieved longer viewing times than other images but that they did not achieve early eye fixations. In short, initial attention to the infographic was low, though attention within the infographic itself was extensive. The authors reflect on the anomaly of this stating that infographics have a ‘special status’ and that more research is needed, including how users read infographics and how visual properties of the infographic compete with the accompanying text. Crucially what is missed within the study is the context of the reading and the factors that play a role in extended viewing times such as interest level or confusion. Holmqvist & Wartenberg (2005) conclude that pictures gain quicker attention due to their established role in helping the reader to determine the subject of the story. In comparison, the motivations of a reader to pay initial attention to an infographic is unclear.

Smerecnik et al’s (2010) evaluated eye tracking data for viewings of text, tabular and graph-based data used for risk communication. Student participants looked at the graphical presentation of data for longer, concuring with Holmqqist & Wartenberg (2005). They also had more fixations aimed at the infographic than at the table or text-only data though did not elicit findings about early or initial fixations that would suggest that they ‘caught‘ attention.

There then appears to be no strong evidence that infographics elicit more initial attention than competing visual elements and, as might be expected, the differences in results may well be due to the different visual qualities of the infographics tested. Content also seems to play a role and this falls beyond concerns of visual form and instead requires the study of audience targeting, audience reactions and distribution methods rather than qualities of the infographic design itself.

**2.2 Attention within the graphic**

There are a number of studies that examine attention paid to particular areas within a graph or an infographic when specific graphic styles are applied. In Renshaw’s (2004) study a significant difference in attention to the title of a graph was found when a simple graph was used rather than a 3D ‘cluttered’ graph. This was accounted for by the tight alignment of the title to the other data elements within the simple graph. This work is useful in highlighting how the Gestalt principles of visual perception can be used (such as the principle of proximity here) in predicting attention areas within a graph or infographic.

In terms of data within the graphic, Renshaw et al (2004) also found, in a comparison of a basic line graph with integrated legend and a 3 dimensional version of a line chart, first fixations of the former were invariably around the legend area and for the latter in the data area. Both were cited as areas that participants believed would aid task completion more readily despite their different visual approaches.

Li and Moacdieh (2014) divided their test charts into areas labelled either data, junk, or data-junk. They found a significant difference between embellished (e.g. those featuring ‘junk’) and plain charts (those featuring predominantly data) as to the amount of time participants spent looking at the data. Results showed that participants spent 66.58% of the time on average looking at the data in plain charts, whereas they spent 29.71% of the time on average looking at the data in embellished charts.

Both studies in this section point directly to gestalt principles and graphic style (e.g. embellishment or plain styles) affecting attention areas though both studies require expansion to extend the scale of the testing on the participants and to provide more contextual insights regarding participant motivation.

**3 COMPREHENSION**

Comprehension has been the largest concern of researchers in relation to graph types (Shah & Hoeffner, 2002). We focus here on reading and interpreting infographics, as does the bulk of the research, rather than understanding how to construct, commission or select them.

Comprehension is measured in the majority of studies by set tasks where participants answer questions about the content of graph of diverse styles. In some cases (Vanichvasin, 2013) self-reporting questionnaires were used though these, it could be argued, are probably more effective at measuring perception rather than performance.

Comprehension refers to the level of understanding achieved by viewing the graphical information. There are various types of ‘question levels’ or comprehension types relevant to visual displays of quantitative data. Wainer (1992) states that there are 3 levels: elementary (locating data), intermediate (identifying relationships) and advanced (analysing what it all means). See Friel et al (2001) for a more comprehensive discussion about comprehension types. Gal (1998) collapsed the three types of questions to two types: ‘literal-reading questions’ (elementary & advanced) and ‘opinion questions’ that involve reading beyond the data. Gal (1998) acknowledges the challenge of the latter type of question because to make a ‘real’ judgement, opinions (as well as the facts) are also involved. Gal (1998) also points out that literal-reading questions usually have a ‘right’ or ‘wrong’ answer and thus we can understand why, in the following section, researchers tend to lean towards measuring more elementary tasks given the assumption that is more measurable. Hawley et al (1998), like Gal (1998), refer to two types of knowledge that can be measured – verbatim knowledge (locating/reading data) and gist knowledge (overall meaning).

There is a plethora of previous work on graph comprehension which mostly stems from the discipline of psychology. The work tends to look at familiar formats (bar and line graphs and pie charts) rather than newer formats or unusual infographic styles. Shah & Hoeffner (2002) produced a useful review of graph comprehension with an emphasis on using them for learning and instruction. Their work has provided an underpinning for this section that also reviews the subsequent 13 years.

**3.1 Locating Data: Accuracy & Speed**

Cleveland and McGill (1984) identified an influential set of elementary perceptual tasks that occur when specific information is extracted from graphs. These perceptual tasks were then empirically examined by Cleveland and McGill (1984) themselves and a number of scholars since. This work resulted in a hierarchical ordering of graphical representations based on accuracy of information extraction. This ranking of graphical representations is shown below:

1. Position along a common scale
2. Position along a non-aligned scale
3. Length, direction, angle
4. Area
5. Volume, curvature
6. Shading, colour

According to this ranking viewing the position of a point within a scale (such as a line graph) is more accurate than viewing the area of a shape. Carswell (1992) however reviewed a further set of 39 experiments that tested out this hierarchy and found only area and volume were poor performers. Such findings point to the need for clear labeling of data areas, particularly those that involve areas or volume for representing size, the former of which is frequently found within contemporary on-line infographic designs (Borkin et al, 2013).

Goldberg and Kotval (1999) identified a number of eye tracking measures that can be used for assessing speed not just accuracy of comprehension. Note how these differ from, say, the reported desirability of a longer fixation time in the attention section. According to Goldberg & Kotval (1999) search efficiency is based upon the number of eye fixations made during a viewing session. A higher number refers to lower search efficiency. According to their study, longer fixations signify difficulty a participant has in locating and comprehending information. The Scan Path refers to areas of interest, cognitive load, and search strategies undertaken. An ‘optimal scan path’ would ideally be represented as a straight line directly to the desired information. The scale path length should be short. This measuring system can prove useful when devising methodologies for assessing efficiencies of processing visual information when specific timed tasks are given.

By employing methodologies such those by Goldberg & Kotval (1999), it is possible to discern the impact of subtle design decisions on comprehension impact. For instance, the position of legends of all charts appears to affect the speed with which participants process a graph. Renshaw (2004) showed that by moving the legend to the side, two areas of fixation were created (and hence a lower search efficiency resulted). Visual clutter (Renshaw, 2004) also added to fixation time, however the particular example chosen in Renshaw’s (2004) study displayed a very large number of design flaws that would obviously create perceptive difficulties. Such studies could now be furthered by using more realistic examples for testing.

There is strong evidence to suggest that the visual presentation of data overall aids comprehension. Garcia-Retamero & Galesic (2010) in a large scale study with the general public in the US and Germany found large improvements in reading accuracy both when icon arrays and when bar graphs were added to numerical information. Highest increases were achieved when the visual aids depicted the entire population at risk.

**3.2 Understanding Relationships**

A number of studies have examined how design impacts on gist knowledge associated with seeing patterns in data and articulating relationships. Bar Graphs have been shown as effective for discrete comparison where the bars are closely positioned (Shah et al, 1999). Divided bar charts should be avoided as they tend to perform less well than simpler formats when difficult questions were given to participants (Schonlau & Peters, 2012).

Line graphs have been shown to be more effective than bar graphs at highlighting x-y trends in data over time (Carswell, 1992; Shah *et al.*, 1999; Zacks and Tversky, 1999). However, line graphs are not as effective for displaying multivariate data, as people tend to only read the x axis as the independent variable (Ali & Peebles, 2013). Gattis & Holyoak J (1996) usefully demonstrated that results were more accurate in terms of judging relations between two dependent variables where the variable causing the change was placed on the x axis. They interestingly discuss how some design decisions are sometimes counterintuitive. For instance, a designer may be tempted to place altitude on the y-axis, to naturally map its vertical properties. However if the altitude is causing an effect, that relationship is more accurately read when it is placed on the x-axis. It has also been suggested that “a large proportion of undergraduate students struggle to interpret line graphs even at an elementary level” (Ali & Peebles, 2013, p.202). Given these difficulties Ali & Peebles (2013) have suggested using colour coding within the lines of the graph to aid comprehension.

The design and location of a graph's legend and its spatial relationship to the data area are extremely important in determining a graph's usability (Renshaw 2004). Carpenter and Shah (1998) concluded that the majority of time spent in graph comprehension involves extensive and repeat reading of information from the axes and legend area of the graph and not looking at the lines themselves. They recommend direct labelling of lines, simple designs and avoiding attempts to represent too many variables in one graph.

Bar charts and line graphs are more effective at comparing values than pie charts. (Schonlau & Peters, 2012). Indeed pie charts, whilst effective for part/whole judgements appear less accurate in the representation of exact numbers. In a large sample (n. 2414) tested by Hawley et al (2008) it was found that pie charts performed the least well for accurate verbatim knowledge in comparison with 5 other formats (table, pictograph, bar, sparkplug and clock). However they did perform the best for ‘gist knowledge’ (for both low and high numeracy participants), a finding which shows potential for usage where a broad indication of a trend is needed and where, perhaps pictograms are inappropriate such as specialist or professional audiences. Returning to Cleveland & McGill’s (1984) taxonomy of visual order, pie charts (that involve angular reading) are rated below, say, graph and line graphs. According to Cleveland & McGill (1984) angle judgments are subject to bias with the following trend evident – that is, acute angles tend to be underestimated whereas obtuse angles are subject to overestimation. Again, clear labeling of data values should accompany pie charts within close proximity to the data areas.

The comprehension of pictographs (icon-based representations of, say, quantities of men and women) is also an area of research, particularly in the area of risk communication and the comprehension of proportional relationships (Paling, 2003). Hawley et al (1998) found, in terms of risk communication, that a pictograph may be a particularly effective option since it was consistently associated with achieving adequate levels of both verbatim and gist knowledge across numeracy levels. Viewers can also recognize proportions fairly successfully with part-to-whole sequential icon arrays (such as blocks of men and women icons). By contrast, proportions are difficult to assess when icon arrays are randomly arranged and also when the icons are purposefully mixed. (Ancker, 2006; Few 2013)

When comprehending risk, the general reader may have difficulty understanding numerators, denominators and proportions. Galesic & Garcia-Retamero (2010), showed in a large scale study, the difficulty found when judging whether ‘1 in 100’, ‘1 in 1000’, or ‘1 in 10’ was the largest risk factor. Such a question was misunderstood by 25% of U.S. participants and 28% of German participants. This is due to participants focusing on the larger number rather than the entire proportion. This comprehension problem is also supported in the review by Ancker et al (2006) and the study by Stone et al (2005) where either numerators or denominators are neglected in favour of the larger number.

The use of more bespoke graph formats, preliminary research suggests, should be used with caution. Goldberg & Helfman (2010) found that spider graphs that required a circular scan were harder to scan and resulted in different, unpredictable scan techniques. One issue with their research is the use of only 5 expert users. Hildon et al (2011) highlight how newer forms of charts, such as funnel charts or more bespoke charts, should be examined further, acknowledging that the field of visualisation is changing more quickly than the pace of academic research

Some studies have identified ways in which readers integrate the information evident in the graph or infographic with the meaning of the surrounding text, rather than simply focusing on one type of graph design. Two design principles (Holsanova et al, 2009) were tested empirically. The first principle tested is called ‘spatial contiguity design’, defined as where verbal and visual information are placed physically close to each other. The second principle, called the ‘signalling’ principle, refers to the layout of elements where attention is drawn to particular information through a clear visual hierarchy (e.g. top-down, left-right). They tested two different infographics with one close to the content and the other further away. The other set involved arranging the frames of an infographic in a serial and radial format. Unsurprisingly they found that the closely arranged and serial formats were more likely to guide the eye to the text and back, in a predictable fashion intended by the designer. Wickens and Carswell (1995) also proposed the proximity compatibility principle, that states that information that needs to be integrated should be close in perceptual proximity.

**3.3 Comprehension and Content**

Ali & Peebles (2013) point out how some errors in graph comprehension are due to misuse of prior knowledge. Content can affect reading the graph where people already have strong views or some knowledge (Freedman & Smith, 1996) known as theory-laden observations. However Freedman & Smith (1996) show that these prior beliefs can be countered by the presence of data and that data lessens the effect of the beliefs. Shah & Hoeffner, (2002) compared viewers’ interpretation of graphs that depicted familiar data for which they had expectations (e.g. number of car accidents) and unfamiliar relationships (e.g. ice cream sales) for which viewers did not have any expectations. Overall, when viewers were familiar with the data, they tended to describe those relationships ignoring data points inconsistent with their personally expected trends. When viewers were unfamiliar with the data they were more likely to describe what the data actually presented. Thus, viewer’s familiarity with the content of the graph affected viewers’ interpretation and influenced whether or not they would describe those trends.

Stone et al (1994) also found that risk when presented relative to other risks (e.g. the risk of smoking in relation to the risk of inactivity) performed better than isolated incidence rates. This again, points to the need to reflect methodologically on the content as well as form of the data presented. It is not clear what the impact of prior beliefs (and particularly emotional beliefs) are more widely on the reading of data or infographics and whilst it is an enormous subject beyond the scope of this review, it is worthy of note.

**3.4 Embellishment and Comprehension**

Embellishment (or “chartjunk”) is described as non-data ink “used as decoration to make a graphic more interesting, such as the repeated use of a picture in varying size instead of the bars of a normal bar chart” (Blasio & Bisantz, 2002, p.90) as well as excessive tick marks or repeated graphic motifs.

Certain types of embellishment have been shown to impact negatively on comprehension. Wickens and Carswell (1995) and Stewart et al (2009) suggested that we read graphs less accurately in the 3rd dimension though Siegrist (1996) and Schonlau & Peters (2012) drew more open conclusions. Gillian and Richman (1994) showed that pictorial backgrounds increased response time and decreased accuracy though in later work (Gillian and Sorenson, 2009) found that where backgrounds purposely differed from the data displayed, accuracy was actually enhanced more effectively than using a plain background. Blasio and Bisantz (2002) showed that high amounts of non-data ink led to slower response times when participants monitored changes in a display, though they couldn’t find a difference in performance in response time between low and medium use of non-data ink. They therefore present a less convincing argument for avoiding embellishment all together, than say, Gillian and Richman (1994).

Bateman et al (2007) found no difference in comprehension accuracy or speed when an embellished chart was presented in comparison with a plain version. In comparison with, say Gillian and Richman’s study, Bateman et al (2007) used a set of ‘well designed’ Nigel Holmes charts that retained legibility despite featuring chart “junk” and this may have aided comprehension.

It therefore appears that the impact of embellishment on comprehension remains unclear in empirical studies. Given the prevalence of heavily embellishment infographics currently in popular culture (Borkin et al, 2013) we may witness an increase in literacy levels of embellished formats though this remains to be seen.

**3.5 Audiences and Comprehension**

WIth the diversity of audiences it is important to recognize the impact of literacy on graph comprehension. Those with dyslexia show difficulty in comprehending graphs, as they have been found to read graphs much more slowly and take longer to process their contents than those without dyslexia (Kim, 2012). Hawley et al (1998) also found that higher numeracy was associated with a better understanding of all the graph formats that they showed. In Retamero & Galesic’s study (2010) visual aids were found to be most useful for the participants who had low numeracy but relatively high graphical literacy skills. We therefore always have to account for audience abilities within research methodologies.

**4. RECALL**

Only a limited number of studies exist that look at the effect of infographics on recall. Merle et al (2014) highlight this knowledge gap stating, in relation to news infographics, that limited empirical evidence exists related to the recall of informative details.

Methodologies for measuring recall include open and cued recall. Open recall involves asking participants to recall either infographics they have seen or facts found in the infographics, either at the end of the research session or a period of time afterward (Bateman et al, 2007). Cued recall involves displaing items that have already been seen once, to ascertain whether they are recognized again. Borkin et al (2013) used an Amazon Turk Intelligence test to recruit ‘workers’ to view a large number of graphics (120 taken from a sample of 420) and indicate when they remembered seeing one before.

Borgo et al (2012) found that embellishment aided both the speed and accuracy of information recalled from long term memory when spatial contiguity design principles were applied e.g. the ‘to-be-remembered’ information was located closely to the image that represented it.

In another study, embellishment seems to have an distinct effect on long term rather than short term recall (for the latter, plain and embellished performed similarly). (Bateman et al, 2007). In a comparative study by Bateman et al (2007) it was found that after a long term gap (2-3 weeks), recall of both the chart topic and the details (categories and trend) was significantly better for embellished charts than plain charts. Li, H., & Moacdieh, N. (2014) found also a positive correlation between use of embellishments and short term recall memory though again only small samples of students (n.15) were used in their study.

Zikmund-Fisher et al (2014) found thatrisk recall was significantly higher when using more anthropomorphic icons (restroom icons, head outlines, and photos) than with other icon types. Mason et al (2014) found thatbar charts led to greater recall of a key risk message though only among the most numerate participants.

Borkin et al (2013) claim a number of visual qualities aid memorability of visualisations. These were listed as: extensive use of colour, inclusion of recognizable objects, unusual visualisation types, use of pictograms and use of embellishment. They acknowledge though that remembering a design is different to remembering a message held within the design and so call for future research that combines the testing of both the form and the content on memorability.

**4.0 BEHAVIOURAL CHANGE**

There is little research regarding actual behavioural change to date partly due to the breadth of the infographics’ content studied (Bateman, 2007; Borkin et al, 2012) and the student focus of many of the studies. It is also difficult to measure behavioural change of a communicated message without longitudinal studies. There is however a large body of work regarding decision making and information presentation more broadly (see the literature review by Kelton et al, 2010). Decisions in such studies range from business or purchasing decisions to potential treatment choices. In most cases studied, the decisions are hypothetical.

Liu, C. C., & Lo, C. H. (2014) found that presenting different product performance charts in different formats (bar charts, count charts and radar charts) resulted in different evaluations of the products and that using radar charts (where the data display covers a wider area) appeared to have a more positive influence that either count or bar charts. The scale of this particular study however, was unclear. Speier (2006) found that participants were more confident of their decisions when using tables rather than graphs, despite the fact that for some tasks, graphs produced more accurate responses. There, then, is much potential is evaluating emotional as well as cognitive aspects of information presentation.

Stone et al (1997) found that graphical displays made participants take the communicated risk more seriously (e.g. pay more for safer option) than if just displayed numerically. The style of graphic however didn’t appear to make a difference. One of the key issues in the methodology relates to the relative sizing of the numerical version vs the graphical form. The latter was much more dominant in the visual field given its size and thus there are more visual variables present than were actually accounted for in the discussion. Evaluating their study does highlight the issues involved in testing different forms whilst attempting to retain equality of as many visual variables as possible. Chen and Yang (2015) also found that presenting risk information in table or graph rather than text format helped to elevate participant’s sense of risk.

Stone et al. (1994) also showed that presenting risk information in relative risk form (e.g., that a safer product reduces the risk to half that of another product) led to more risk avoidant behaviour than simply giving the absolute risk sizes for the two products. Relative risk may perceptully inflate the difference between two risk-specific behaviours despite the fact the absolute risk may be statistically small overall..

Hawley (2008, p.453) state that little research has evaluated the impact of graphical formats

on actual medical treatment choices, though they acknowledge the impact of graph format in verbatim and gist knowledge (discussed above). If information cannot be understood it cannot impact usefully on decision-making. Hawley et al (2008) also collected and analysed views on trustworthiness - an important characteristic of any infographic. They found interestingly that the non visual form .e.g. the table was rated more effective, trustworthy and scientific. However, the pictograph that performed well across all comprehension tests too was favorably rated for trustworthiness.

There is also useful burgeoning qualitative research (Le et al, 2013) that argues for more theoretical frameworks to be constructed based on testimony from real users. Le et al (2013) isolated particular areas of concern and favour when interviewing health providers about novel methods for presenting health data, including issues of trust, how they might be applied in reality or how they might aid decision making.

Behavioural change must be seen as one part of chain of functions, dependant on the other effects of attention, comprehension and recall, as well as the myriad of other influences that effect choice. It is certainly an area that demands more attention by researchers and organisations, particularly where an economic case is required for their use.

**5.0 Appeal and Personal Preference.**

Broadly, there is increasing interest in the role that appeal can play in an infographic’s ability to communicate effectively. In 2007, Lau and Moere proposed the term ‘information aesthetics’, and listed three potential characteristics that may affect the engagement of lay audiences when they view data. These characteristics are described as (1) design quality (visual style and user experience) (2) data focus (the communication of meaning instead of facts and trends) and (3) user interaction (flow, user engagement and collaboration). These aesthetic concerns are indicative of more contemporary research, expanding the field of cognition via efficiency and clarity to cognition via engagement (Hullman, 2011)

Inbar, Tractinsky & Meyer (2007) found that students preferred to see charts or graphs that had a degree of embellishment rather than being purely plain. Quispel & Maes (2014) found that graphic design students preferred more complex and diverse formats than ‘lay’ students, highlighting possible disparities between those that produce and those that view infographics. Both studies also used a fairly small sample size and thus could be further substantiated. Hinting at criteria used by students doesn’t aid in understanding the wider preferences of a more diverse population. It does however show the importance of employing a mixture of interested groups in the research.

Hildon et al (2012) found in their relatively small scale study that familiar presentation styles such as star ratings and traffic light were preferred to more unusual formats. In Bateman et al’s (2007) study it was found that participants found the embellished infographics more ‘enjoyable’ than the others and were much preferred to plain graphs. What the impact of this preference is in terms of impacting on attention, comprehension and recall is not clear in Bateman et al’s (2007) study and this area would benefit from more research. From these two studies it appears there is a need to balance both embellishment (to differentiate and decorate) and familiarity in a design (e.g. not to push novelty to extremes where visual form becomes unfamiliar).

Preece et al (2012) in a study that sought both preference and performance data from expert users using a variety of chart design, concluded that it’s dangerous to rely on preference alone. They found some serious usage problems with ‘popular’ designs and called for more balanced researching. This work related to specialist users, in this case, clinicians and thus requires extending out to a lay audience. In a different study, restroom icons were cited as most preferred over other icon types (Zikmund-Fisher et al, 2014) and *also* performed well in other tests, thus high appeal and high performance are not necessarily mutually exclusive.

Conclusion

This work highlights the scarcity of robust evidence in certain aspects of infographic design despite the large amounts of infographics published and shared every day. Whilst there is much research focusing on say, familiar graph types and comprehension, there is less research available focusing on embellished infographics that are visible in the contemporary press and commissioned by organisations.

In terms of attention, there is conflicting evidence concerning whether infographics can gain initial attention and this seems highly dependent on the surrounding context and the size of the graphic. The visual display of data via bar and line graphs have been shown to be quicker for understanding trends and relationships than text only or purely numerical data. Certain aspects of infographic design also impact upon comprehension, such as location of legends and arrangement of icons. There are still comprehension difficulties for significant numbers of the general population when looking at even basic chart formats such as pie charts, despite these being a common feature of popular infographics. Embellished infographics have been shown to impact positively on recall though few studies of scale and scope exist. There are few studies examining adherence and infographics though use of graphics has been shown to aid decision making. Generally embellishments have been found to be more appealing than plain graphs, these do not always aid comprehension.

Overall there is a wealth of research concerning standard graph types in relation to comprehension but very little evidence base for, say, the use of contemporary infographics or the use of embellishment types in infographic design. Except for the area of risk communication with patients, the bulk of research has been done on relatively small numbers of students and thus needs to be viewed with caution for wider application in the area of public health, or indeed many specialist areas.

Tractinsky & Meyer (1999, p.398) point out that “there seems to be a gap between research driven guidelines for information presentation and information presentation in practice and this gap is widening with the introduction of new presentation technologies”. The gap is also apparent in the number of studies performed only on student audiences in hypothetical situations. We need a greater understanding of the motivations of the audience as well as of the maker. Ancker et al (2006) states that education level, literacy, numeracy, and culture are also likely to be useful areas of research.

Most of the research focusing on comprehension relates to conventional graph formats and predates infographics where often various data representations are brought together in one space together with, say figurative imagery. The study by Borkin et al (2013) reviewed 1721 infographics from visual.ly.com and found that only 29% of them featured a single visualisation. To date there is no research that examines the more common multiple frame format of infographics and the impact this has on attention, recall, comprehension and adherence. Whilst studies report visual clutter (Renshaw, 2004) as a problem it is currently unclear how much clutter is tolerable and the impact of a large number of frames upon either verbatim or gist knowledge.

There are many potentially significant theories being discussed about contemporary infographics - the role of narrative (Segel & Heer, 2010) or the role of visual rhetoric in infographics (Hullman, 2011) - and there is much scope for extending the current scope of empirical work in this area with actual users. In a business context, Tractinsky & Meyer (1999) discuss the need to consider other objectives of presenting information such as persuasion. Again, these are areas that are relatively unexplored through either quantitative or qualitative measures.

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