Benefits of Presenting Information Visually and Guidelines on How to Do It

An Introduction to Static Information Visualizations for Novices

Margrethe Ellstrøm
Department of Product Design
Norwegian University of Science and Technology

ABSTRACT

This paper set focus on *whether one should use information visualizations,* and *what are the benefits of making information visual?* Several studies state that information visualizations are beneficial. By visualizing information, one can see patterns and gain new insight. Insights from visual sensory can be as quick as 300 milliseconds. Visualizations help in structuring information, by placing information in context and making it more memorable. They also exploit the fact that visual processing involves almost 50% of the brain. Psychologists support the use of information visualizations and visualizations are being used in education with good results. At the same time, it is important to remember that visualizations can be biased and can be used to persuade people [40]. With the increasing availability of visualization tools, making visualizations has become accessible to new user groups. Effective visualizations often follow guidelines such as principles from color theory, Gestalt, cognitive theory and graphical embellishments to highlight key information. Information visualizations can be attractive without compromising key information. In fact, the graphical embellishments added for design effect can even be beneficial to conveying the information.

KEYWORDS: Information Visualization, Embellishment, Chart Junk, Knowledge Acquisition, Visual Explanations, Cognitive Load.

1. INTRODUCTION

The first evidence of human visualizations are cave paintings dating back 35 000 years ago [1]. Since then, humans have developed further ways of envisioning information. To envision information, as Tufte describes it, is *'to work at the intersection of image, word, number and art'* [2]. Abstract data visualizations were first invented in the late 1750's [3] and information visualization continued to evolve with the development of visualization software in the 1980's [4]. With the increasing use of visualization tools, combined with the availability of data, information visualization has gained a widespread influence and popularity [5]. This article sets out to explore research that supports this trend. The article will address *whether one should use information visualizations,* and *what are the benefits of making information visual?* Another question that will be further investigated is if there are any general guidelines on *how* to make information visualizations, and in particular the role of embellishment, graphic elements used as decoration. To best answer these questions, the article will use research from psychology, information visualization and design--specifically cognitive and educational psychology, best practices from information visualization and graphical principles from design. This article is

written for novices in the field of information visualization and provides an overview of some of the literature surrounding *why* and *how* to use information visualization. The scope of this article is not to provide an answer to which information visualization is the best to use, but it will give examples of some commonly used information visualizations types and their strengths.

2. METHOD

This article is a review paper based on research articles from psychology, information visualization and design. Articles have primarily been found by using SCOPUS and Google Scholar. Words such as information visualization, infovis, graphics, infographics, knowledge acquisition, learning, cognitive processing, illustrative effects, chart junk and embellishment have been used as search words in various combinations to find relevant articles. Then, to go deeper, article references followed up and it was also searched for keywords mentioned in the introductory article. Literature search led to some books on the topic, generally from the 1980's. These books are being cited in newer articles and are therefore also considered relevant for this article. Older theories will be questioned based on new research in cases where there are conflicting theories and results. Since the use of information visualization is increasing in popularity, it is widely being discussed and written about on the World Wide Web. That is why internet sources such as articles from blogs and the webpages of design offices have been utilized. They are interesting to include in this article since they broach and discuss topics yet to be researched and written about by formal academic practitioners of information visualization. The primary sources of this article are the articles and books that evaluate the use of graphical decoration, later referred to as embellishments and so called 'chart-junk' [3], as well as the effect of using information visualizations to advocate knowledge acquisition. Several of the articles on educational benefits are gathered from the official education research journals, and several of the articles on embellishment are published on IEEE Transactions on Visualization and Computer Graphics. Since the topic area of information visualization is constantly being researched and debated, some of the more recent articles included as sources in this review article have been published during this article's time of writing. The literature has systematically been grouped into the categories: cognitive theories, educational psychology, best practice in information visualization, and articles that focus on the role of visual embellishment. Outlining and mind mapping were used to get an overview of the most interesting findings from the reviewed material. To answer the questions brought up in the introduction, the article will begin the discussion with cognitive psychology to see if theory supports the use of information visualizations and *why*. The following section will use design principles and best practice experiences combined with the findings from psychology to see if it is possible to say *how* visualizations should be made. Four examples of different information visualizations will be given to provide context and to better support the conclusions of this report.

3. RESULTS

3.1 Why Use Information Visualizations

3.1.1 Definition of Information Visualization

Gershon and Page writes that information visualization 'combines aspects of imaging, graphics, scientific visualization, and human-computer and human-information interactions, as well as information technology.' [6, p. 33]. The use of the term 'information visualizations' in this article refers to all information presented visually and will be used interchangeably with 'visualizations' throughout this article. Information visualizations may include (but is not exclusive to): icons, data visualizations, graphic organizers and infographics. These four types of visualizations will be further defined and exemplified in section 3.3.

3.1.2 Biologically and psychologically

To understand *why* information visualization is beneficial, one has to look at how the mind works. The infographic design agency Neomam refers to Human Anatomy & Physiology [7] in their infographic on 'Why Your Brain Craves Infographics' [8] when saying that we are 'visually wired'. Almost 50% of the brain is involved in visual processing and 70% of all our sensory receptors are in our eyes [8]. Research shows that it can take less than 300 milliseconds for humans to understand the meaning of a visualization [8,9]. As mentioned in the introduction, visualizing information dates back 35 000 years in human history [1]. Hand-in-hand with storytelling, humans have developed efficient ways of conveying information through visualizations and stories [6]. Troy and Möller [10] summarizes how visualization can support cognition in the table in Figure 1. McLoughlin and Krakowski [11] say that cognitive psychologists are under the impression that if learners work in multiple modes (such as text and graphics), the working memory processing is more effective. [11]. They also write that the thought of learning from visual elements has gained great momentum and that visualizations are playing a greater role in education. McGrath and Brown [12] write in a summary of several studies that students' visual senses should be exploited by using visual learning. Visual learning enhances the learning outcome and engages the students' interest [12]. In Robert's [13] research on visualization display models, he points out that visualization consists of a presentation process as well as a discovery process. Information needs to be presented in a way that augments the reader's understanding of the underlying information as the reader discovers new insight. This supports the use of information visualization as an educational tool, especially when people have to make their own visualizations. Van der Veen [14] writes that when students make drawings of the content of an article, or a concept, it reveals if their understanding is correct. He also writes that the drawings give an insight into how they have processed the information [14]. McGrath and Brown support this view, and ads that the process of making the visualizations will help clarify the information [12]. It is also important to reflect upon how information visualization affects the readers when trying to find out *why* they should be used. McCandless talks about this in his TED Talk 'The Beauty of Data Visualization' [15]. In his presentation he says that information visualizations can convince people to make a choice based on how the information is presented. He gives examples of information visualizations that can easily persuade people by presenting a right or wrong impression of a topic. Combining misleading design with the fact that humans can understand the meaning of a visualization in less than a second, this article finds it relevant to point out that visualizations have the possibility of being used as an effective tool for propaganda. It would be interesting to research how information visualizations can facilitate behavioral changes and value judgment.

3.1.3 Technological development

With the amount of accessible data that we have today, one can say that we are living with constant information overload [8]. A lot of the visualization tools can help us sort and present the data, and make us see patterns and relationships that we possibly would have missed out on otherwise. The organization of data these tools provide is explicitly mentioned in the table by Troy & Möller [10] in Figure 1. Visualization tools are now being used by practitioners from a wide span of professions for a diverged set of problems [16].

Method	*Description*
Increased Resources	
Parallel processing	Parallel processing by the visual system can increase the bandwidth of information extraction from the data.
Offload work to the perceptual system	With an appropriate visualization, some tasks can be done using simple perceptual operations.
External memory	Visualizations are external data representations that can reduce demands on human memory.
Increased storage and accessibility	Visualizations can store large amounts of information in an easily accessible form.
Reduced Search	
Grouping	Visualizations can group related information for easy search and access.
High data density	Visualizations can represent a large quantity of data in a small space.
Structure	Imposing structure on data and tasks can reduce task complexity.
Enhanced Recognition	
Recognition instead of recall	Recognizing information presented visually can be easier than recalling information.
Abstraction and aggregation	Selective omission and aggregation of data can allow higher level patterns to be recognized.
Perceptual Monitoring	Using pre-attentive visual characteristics allows monitoring of a large number of potential events.
Manipulable Medium	Visualizations can allow interactive exploration through manipulation of parameter values.
Organization	Manipulating the structural organization of data can allow different patterns to be recognized.

Figure 1: Troy and Möller's table on how visualization can support cognition [10, p.73]. The table gives examples of different methods one can use when making visualizations, and a description of why they support cognition.

3.2 Aspects to Think About When Designing Information Visualizations

3.2.1 Accuracy

One of the main focuses of this review article is on graphical embellishment, style and 'chart junk' (unnecessary graphic elements that do not communicate information), and the effect these graphics will have on information visualizations. Tufte [3] proposes a maximization of the data-ink ratio to make the most efficient visual displays. The data-ink ratio is the amount of ink used for displaying the data divided by the total amount of ink used in the visual display. His theories have been questioned by several research papers [17,18,19,20] and will be further discussed in the paragraph about embellishment. He also presents six principles [p.77, 3] to prevent the data from being misleading: (1) Graphics displaying quantified data should be directly proportional with the numerical amount that they are supposed to visualize. (2) Labeling ought to be written on the graphic itself and should be clear and thorough. (3) Do not show design variation, but show variation in the data. (4) Standardized units are almost always the best way of displaying monetary time-series displays.

(5) There should not be more dimensions pictured in the visualization than it is in the actual data. (6) Do not let the graphical elements quote the data out of context.

Another interesting aspect to remember on the topic of preventing the data from being misleading is to be as unbiased as possible when making them. In the TED Talk by McCandless [15] he admits that it was hard for him to visualize the political infographic in Figure 2, without letting his own political view influence the visualization. If Tufte's [3] 6 principles are used when making visualizations of quantitative data, one can reduce the risk of portraying the data in a biased way.

The ultimate form of information visualizations is also based on the wanted outcome. As mentioned, McCandless [15] said that visualizations can persuade people to take actions or form a biased impression. If this is the goal of the visualization then one should perhaps not follow Tufte's 6 principles [3], but rather focus on how to give the impression you want to by adjusting the visualizations of quantitative data to suit your intentions. A study on 'How Users Read on the Web' by Nielsen [21] showed that people scan the pages instead of actually reading them. He found that by making the information concise, scannable and objective, the usability increased with 124%. This could also be exploited in information visualizations since a lot of them are being presented on the web.

3.2.2 Cognitive load

When making information visualizations it is also important to prevent cognitive overload. Cognitive load is related to the capacity of the working memory. An overload may occur when several processes work simultaneously to process the information [22]. Mayer & Moreno [22] writes about three cognitive demands: essential processing (germane load), incidental processing (extraneous load) and representational holding (intrinsic load). Essential processing is the cognitive process that is needed to make sense of presented material. Examples of essential processing include selecting images, selecting words, organizing images, organizing words and integrating them. The incidental processing is the processing that occurs incidentally because of the way the information is designed, such as when a reader uses cognitive capacity on processing embellishments. Representational holding refers to the cognitive capacity one uses to hold a mental representation for a period of time in the working memory. If a picture is presented on one page and the description of it on another page, you would have to hold on to the picture in your working memory while reading the description on the other page. Mayer & Moreno [22] present several conclusions on how to reduce cognitive overload, in which some of them seem appropriate to apply to information visualizations. The load-reducing methods that this article consider relevant to include are: *segmenting* (allowing time between each chunk of information and having the learners control when to see the segmented information), *pretraining* (pretraining readers in names, components and systems), *weeding* (reducing the amount of extraneous material to increase coherence), *signaling* (indicating how to process the information), *aligning* (reducing the need for visual scanning by having related text and illustrations near each other), *eliminating redundancy* (keeping the reader from having to read the same text several times) and *synchronizing* (minimizing the need for representational holding by synchronizing all elements in the same view).

3.2.3 Embellishments

Contrary to Tufte's [3] data-ink theories, Vande Moere et al. [23] start off with Norman's famous mantra 'attractive things work better' in the introduction of their evaluation of the effect of embellishments in information visualizations. They made three visualizations based on the same information and varied them in their use of embellishments. The visualizations represented

namely an analytical style, a magazine style and an artistic style of information visualization, with an increasing degree of embellishments. Despite several critical observations concerning their methodology (in particular the use of an online comparative test), they make conclusions regarding the impact of style on usability, on the *depth* of insight and on *what kind* of insight. When it comes to usability, the analytical style performed the best, and they conclude that if usability is the most important aspect, one should not use embellishments. When it comes to the depth of insight, there was no difference in performance by the three different visualization types. On the other hand, they discovered some differences when it came to what kind of insight people received. The most embellished visualization made it harder for people to see patterns in the information, but it amplified insight acquired by reasoning, interpretation and reflection [23]. The most embellished visualization in Vande Moere et al.'s study was made at the expense of pattern finding qualities. This review article considers it wrong to conclude that all embellishment will reduce the pattern finding qualities based on the findings in this particular study. The set of Gestalt principles is one example of tools that can be used to enhance pattern finding qualities of visualizations. The set of Gestalt principles will be discussed more thoroughly later in this article. The empirical study on the use of graphical embellishment by Borgo et al. [20] shows that by adding embellishments, the response time increased in the visual search task. This supports (to some extent) the conclusion proposed by Vande Moere et al. [23] that embellishments reduce usability. Borgo et al. also found that embellishment in visualizations is beneficial for the working memory and the long-term memory, with the premise that the embellishment is grouped with the corresponding information. When it came to concept grasping, findings could not determine whether embellishment increases performance, but they could conclude that it did not reduce the performance of their participants. This implies that the data-ink ratio proposed by Tufte [3], is not correct in all cases and should not be followed uncritically.

3.2.4 Gestalt

The Gestalt theory of perception is based on how humans sense and organize visual impressions such as proportions, sizes, direction, color, texture and grid [24]. As mentioned briefly earlier, Gestalt principles play an important role when visualizing information. For example, Mayer & Moreno's suggestion of aligning text and illustration [22] can be linked to the Gestalt principle of grouping and proximity. One Gestalt principle that could be used for *signaling* is *continuation*, to give clues on how to view the visualization. Continuation is when graphical elements make your eyes go from one object to another such as lines. The principle of closure is interesting to mention with Tufte's [3] data-ink in mind. Closure is when an incomplete visual element gives enough clues for people to add the missing information to perceive it as a whole. A good example of this is how our mind finishes the circle in Figure 3. Based on the principle of closure, it is possible to reduce the amount of ink used without losing the impression of the visual element as a whole. Another Gestalt principle is based on how similarity and differences in shape and color can make it easier to differentiate visual elements. Such differentiations can help offloading work to the perceptual system, which is one of the methods presented in Troy and Möller's [10] table on how visualization can support cognition.

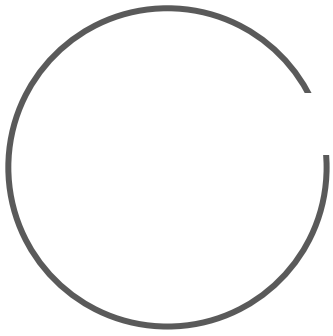

Figure 2: An example of the Gestalt principle continuation.

3.2.5 Colors

Colors can also be used to differentiate information based on Gestalt theory [24]. When using colors it is important to remember that colors can be a statement in and of itself. Colors can be pre-attached to affordances such as green meaning 'go' and red saying 'stop'. These affordances can vary when associated with different settings and objects. If these cues do not work as assumed, Weinschenk [25] describes our reactions to these discrepancies as annoyed and frustrated. Most people who use hot and cold tap water would be quite surprised if warm water came out of the tap when positioned on the blue side. According to an article on color theory [26], colors also have the effect of evoking emotions. These feelings are partially based on cultural tradition and personal preferences. It is important to remember that the feelings can differ between individuals and societies. In addition to differentiating information and evoking emotions, colors are also important to make visualizations memorable. Borkin et al. [19] found that visualizations using seven or more colors were more memorable. These visualizations were mostly from the category 'infographic' and included often illustrations of human recognizable objects. Combined with the thought that attractive things work better [23], it is a goal to make the color palette memorable and aesthetically pleasing. When working with colors it is also important to consider contrasts for readability and color blindness.

3.3 Example of Four Different Visualizations

There are many ways of visualizing information. This chapter will give example of, and define, four types or information visualization and their strengths. The visualizations are: *icons, data visualizations, graphic organizers* and *infographics*. The selection of visualizations has derived from an interest in infographics and is therefore consisting of visualizations that are used in, or are closely related to, infographics.

3.3.1 Icons

Figure 3: From left to right: hollow icon, solid icon, pictogram, icon as logo.

Definition: A visual representation of an action, object or information presented as a visual element such as pictograms and simple signage.

Usage: Icons are suited to be used when information need to be grasped quickly, under the condition that they are intuitive, such as road signage and labeling on e.g. chemicals. Pictograms representing the depicted information work better than unfamiliar, constructed symbols since unfamiliar symbols imply the learning of the pictogram [27]. Standards should be used if they exist, especially if the outcome of misinterpreting the icon may cause severe risk. Icons can also be considered art, and there is an ongoing art development project where they try to express more complex information such as philosophical considerations through simple icons such as pictograms [28]. In the field of graphical user interfaces, icons are continually developing and there are debates on how so-called 'hollow icons' affect usability [29,30]. Icons are also good for labeling since they can represent a set of requirements or standards and take up little space, such as washing labels and 'do not throw in trash'-signage on batteries. They are easy to remember and are often used in logos for branding. Icons can be used as communicative or decorative elements in other information visualizations.

3.3.2 Data Visualizations

Figure 4: 'The Billion Dollar-o-Gram' is comparing billion dollar amounts to give people an understanding how much a billion actually is by visualizing e.g. costs of the Iraq and Afghanistan war with money spent on video games and alternative medicine.

Definition: Data visualization is in this article defined to be the visual representation of quantitative information. This includes e.g. pie charts, line charts, graphs and word clouds.

Usage: Data visualizations can make data more memorable and can engage people by placing data in context [15]. They are also a good tool for structuring complex data sets, finding new relations and facilitate pattern finding. Tufte has written several books on when and how to display quantitative information visually [2,3,31,32]. Data visualizations are beneficial to use when the information is quantifiable. Graphics generated from quantitative information can be made automatically by software [33].

3.3.3 Graphic Organizers

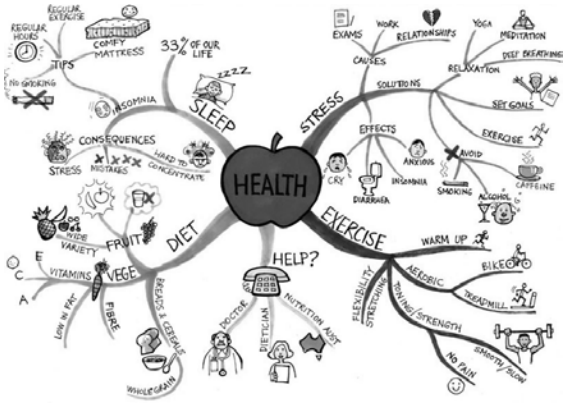

Figure 5: Example of a mind map with graphical embellishment.

Definition: Robinson and Kiewra write that 'graphic organizers use a spatial format to convey concept relations' [34, p.455]. The term in this article includes among others matrices, tree diagrams, flow charts and mind maps.

Usage: Graphic organizers help to sort out information and create mental models that help the users to structure their knowledge. Mind mapping, in combination with color, images, codes and dimensions, can foster knowledge acquisition and engagement among students [35]. Robinson and Kiewra write that matrices are good for arranging concepts and attributes to do comparison between the concepts [34]. Flow diagrams are useful when wanting to visualize a flow in actions or information such as an outline of an article [36]. Tree diagram can organize information spatially and displays the hierarchical relations [34]. One of the goals of graphic organizers is to have them constructed in a way that would make it impossible to look at them without acquiring new knowledge of the relations of concepts [34,36]. Flow charts and tree diagrams are being used as tools in graphical user interface development to show a wanted flow of an application, or to make a site map of website.

3.3.4 Infographics

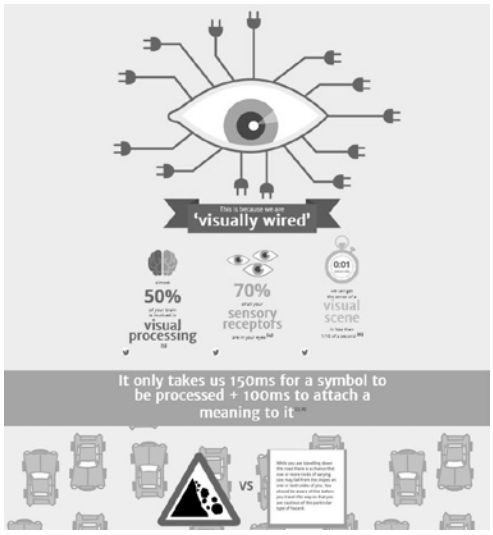

Figure 6: A part of the infographic by Neomam information graphic agency called Why your Brain Craves Inforgraphics.

Definition: Infographics are visual representations of information, data or knowledge and are made as a combination of aesthetical values, the precision of quantitative data and the narrative approach in storytelling. In this article, infographic refers to the definition of the 'Editorial Infographics' provided by Lankow et al. [33] which is infographics to use in print, online publications and blogs.

Usage: Infographics are a combination of different visualizations. They can include statistics in data visualizations, graphic organizers of concepts and information, illustrations and large typography [33]. Lankow et al. [33] write that there are no clear definitions as to what an infographic should include or leave out. This has caused a great variety of infographics online. One of the benefits of an infographic is the ability it has to guide the viewer. The narrative approach is beneficial to instructional infographics, such as how to tie a tie. Infographics can also leave the viewer with an intended message and possibly make people take action [33]. Infographics engage viewers by using colors and aesthetical chart junk to grab people's attention. They are easily spread online and have become a commonly used tool in online marketing. They are useful to make if the aim is to editorialize information to suit the wanted value judgment outcome [33]. Infographics can, as graphic organizers, be a good tool to use when wanting to display spatial relationships.

3.4 Correlations of the presented Visualizations

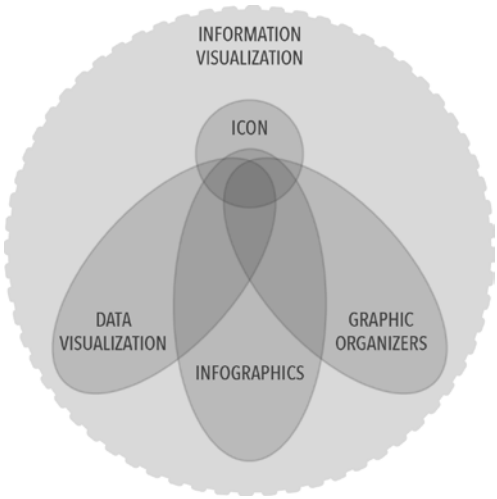

Figure 7: The figure shows the suggested correlations of visualizations brought up in section 3.3.

The figure is inspired by Venn diagrams and gives a suggestion to the correlations of the presented information visualizations. Intersecting areas show the different combinations of the visualizations. I.e. an infographic can include icons, data visualization and graphic organizers or leave them all out. In the latter case, the infographic could be using other visualizations than the ones brought up in this article such as images, maps and scientific visualizations. The figure also shows that when combining graphic organizers and data visualizations, the result is always a form of infographic. Icons are differentiated in shape in the diagram due to its simplicity in comparison to the other visualizations. Other than that, the sizes do not represent the frequency of use or sizes of the visualizations.

	ICON	DATA VISUALIZATION	GRAPHIC ORGANIZERS	INFOGRAPHICS
BIOLOGICALLY PSYCHOLOGICALLY	Research has been done on the emotional effect of pictograms [37]. It can take less than 300 milliseconds to understand the essence of an icon [8,9].		'The principal function of the organizer is to bridge the gap between what the learner already knows and what he needs to know…' [39, p.6].	Neomam Information Graphic Agency write about how we are 'visually wired' in their infographic 'Why your Brain Craves Inforgraphics' [8].
TECHNICAL DEVELOPMENT	We have the tools to make icons realistic representations of what they represent, but trends are again going back to simpler representations [29].	Data visualizations were first invented in the late 1750's [3] and continued to evolve with the development of visualization software in the 1980's [4].	Robinson [36] says that the graphic organizaers are a development of the 'Advanced Organizers' of Ausubel from the 1960's.	
ACCURACY	There is an ongoing project on how to express complex messages and philosophical considerations' [28] through simple signs.	Tufte [3] presents 6 principles to prevent data visualizations from being misleading.	The review paper 'Graphic organizers as aids to text learning' [36] presents a review of recent graphic organizer research and their findings.	Infographics can be misleading if the creator is biased when making it [15]. They can also be made with the intention of being biased to persuade the viewer.
EMBELLISHMENT	Jacob Nielsen [38] writes about how the icons that was simplified the most were the most efficient.	Tufte's theories on maximizing data-ink ratio [3] have been questionned [17,18,19] and even proven wrong [20].		Hullman et. al [17] provides evidence that low data-ink ratios may be functional and may have several benefits such as personalization and engagement.
COGNITIVE LOAD	By using familiar icons, the chance of cognitive overload is reduced. This is in accordance with the thought of reducing cognitive load by pretraining readers [22].		Graphic organizers are proven to facilitate memory and learning [34,36,39] and reduce cognitive load by segmenting, weeding and signaling [22].	Mayer & Moreno's theories on essential processing , incidental processing and representational holding should be taken into concideration [22].
GESTALT	The set of Gestalt principles [24] is a good tool for visualization since they exploit how we sense and organize visual impressions. They let you be aware of how our vision is noticing patterns and also absent of pattern.			
		An important feature of data visualizations is to enhance pattern finding abilities [5].	Graphic organizers can benefit from grouping and proximity to exploit the Gestalt principles.	
COLOURS		Troy & Möller [10] points out that colours are not equally distinguished by people, and that picking colours for data is not easy.	Color can increase the retention of information by structuring information [35].	Research shows that visualizations including 7 or more colours were more memorable [19]. This did not refer to the content, but the visualization as images.

Figure 8: A matrix of some of the more general theories from sections 3.1 and 3.2 applied to the specific visualizations in section 3.3

3.4 How General Theories Can Be Applied to Specific Visualizations

The matrix shown in Figure 8 was constructed to help readers find relevant literature from this review article. The rows represent the headlines of the chapters in section 3.1 and 3.2 while the columns each represent one of the visualizations from section 3.3. The matrix was also made to see how the more general theories in section 3.1 and 3.2 could be relevant to the specific visualizations from section 3.3, and may therefore, to some extent, also work as a summary.

4. DISCUSSION

The questions brought up in the introduction were *whether one should use information visualizations,* and *what are the benefits of making information visual?* Another question was is if there are any general guidelines on *how* to make information visualizations, and in particular the role of graphical embellishment in information visualizations.

There are several arguments as to *why* visualizations are a good way of presenting information. The biological arguments referred to in this article cite how the brain interprets pictures and that 70% of all our sensory receptors are in our eyes [8]. Troy and Möller presents a good overview on how visualization can benefit cognition in Figure 1 [10]. It has also been done studies in educational psychology that supports the use of visualizations [40]. Even though these theories are from the 1980's they are also supported by more recent studies [12,14] and continue to be valid today. Visualization tools are no longer only intended for graphical designers and researchers, but are here for everyone to use. As a result of this development, we need to be critical of information presented in visualizations, in the same way that we should be critical of textual information presented online (for example, in assessing the validity of Wikipedia articles [41]). Also, in pace with the increasing usage of such tools is also the need for research on the empirical evaluation of these tools [42]. Without further comparison to Wikipedia, information visualizations are easily distributed online and they may often appear to represent research material without actually referring to the source of the information. This may lead to the dissemination of false information and can weaken people's trust in information visualizations. An additional concern is that visualizations can very easily represent the opinion of the person that made it, even when it is presented as objective data. McCandless [15] has experienced the importance of being unbiased when making political visualizations. Tufte's 6 principles [3] are good guidelines to prevent visualizations of data from being misleading when using graphics.

Another starting point for this article was the desire to find out if there are any guidelines on *how* to make the best information visualizations, and in particular the role of embellishments in visualizations. As mentioned in chapter 3.2, Tufte's principles [3] are meant to be such guidelines, but his theories have been questioned [17,18,20]. Hullman, Adar and Shah discuss how visual difficulties such as embellishments can benefit comprehension and recall [17]. According to Tufte [3], the maximization of the data-ink ratio is a good way of measuring the efficiency of a graph. Hullman, Adar and Shah write that people learn by interacting with the visualization and as a result of spending more time decoding the information, they will be more likely to recall it later [17]. Borgo et al. are also supporting this and conclude that by adding visual embellishment, the retention of information is improved, but at the expense of an increase in processing time [20]. It can be concluded that the designers of information visualizations need to balance the focus on cognitive efficiency with the use of visual difficulties based on the wanted outcome [17,18].

Other guidelines refer to cognitive load [22], the use of Gestalt principles and color. The set of Gestalt principles is based on perception theories and is a good set of principles to follow, or to at least be aware of, when designing visualizations. Color theory was also included because of the ability colors have to differentiate information and evoke emotions. Jakob Nielsen's [21] study of how people read on the web is claiming that people do not read the text, they only scan it. This may be one of the reasons why information visualizations have become so popular since the text in information visualizations is often concise and the visualizations themselves have a scannable layout.

Even though there are guidelines to follow, there is not one right answer as to how information should be visualized. This article is meant to be an introduction to information visualization and is therefore focusing on the general benefits and guidelines to all visualizations. To make effective visualizations one should be aware of these theories and guidelines and use them actively. By using colors, Gestalt principles and embellishments consciously, information visualizations can be attractive without compromising the information. The selection of examples given in section 3.3 is chosen to show some of the diversity that exists in information visualizations.

5. CONCLUSION

This review paper focuses on '*Why one should use information visualizations?'* and '*What are the benefits of making information visual?'.* Several of the reviewed articles believe that information visualizations are beneficial [4,11,17,34,36,39,40]. By visualizing information one can see patterns and gain new insight. Insights from visual sensory can be as quick as 300 milliseconds [8,9]. Visualizations are supported by psychologist and are being used in education with good results [12,14]. With the increasing availability of visualization tools, making visualizations is also spreading to new user groups. This makes it important to remember that visualizations can be biased and are potentially suited to be used to persuade people [15]. There are principles from color theory, Gestalt, cognitive theory and embellishments that can be used as guidelines when making visualizations. Information visualizations can include 'chart junk' without compromising the information. Embellishment has even proven to be beneficial if the goal is to make people remember the visualization in itself [19] or foster insight acquired by reasoning, interpretation and reflection [23] and it can also beneficial for both working memory and long-term memory [17,20].

5.1 Future Research

Information visualization should be further researched as the field is evolving. A topic that needs to be researched is what are the best methods to measure the effects of information visualizations? In pace with the increasing use of visualization tools, there is also the need for research on the empirical evaluation of these tools [42]. It would also be interesting to research how information visualizations can facilitate behavioral changes based on the theories of McCandless [15].

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FIGURES

Figure 1: Tory, M., Möller, T. (2004) Table from Human Factors in Visualization Research [10]
Figure 2: Margrethe Ellstrøm (2013) for this article
Figure 3: Hollow icon, solid icon and pictogram by Margrethe Ellstrøm (2013) for this article, logo from www.wikipedia.org (Accessed 04.12.13)
Figure 4: McCandless, D. This particular visualization is also one of his examples in the TED Talk [15] http://store.informationisbeautiful.net/product/billion-dollar-o-gram (Accessed 04.12.13)
Figure 5: http://learningfundamentals.com.au/resources/#lightbox/2/ (Accessed 04.12.13)
Figure 6: Neomam information graphic agency, http://neomam.com/interactive/13reasons/ (Accessed 29.10.13)
Figure 7: Margrethe Ellstrøm (2013) for this article
Figure 8: Margrethe Ellstrøm (2013) for this article