Chapter 1: Introduction

This thesis describes an approach to the use of information graphics in the scientific discipline of health technology assessment. As such, it is a work that brings together the diverse disciplines of information design and a particular area of evidence-based health research. It is hoped that the methodological discussion and original research detailed here might provide useful and practical advice for those working in either information design or HTA. However, its particular aim is to show how the two disciplines can both be strengthened by learning from each other.

This introduction is intended to provide background on ‘information graphics’ and ‘health technology assessment’. This leads to a working definition of these terms for the purposes of this research project. The chapter then describes the relevant domain of enquiry for the research. The last part of the chapter sets out the research question, to be addressed by the rest of the volume.
1.1 Information graphics

1.1.1 A brief history

A complete history of information graphics is beyond the scope of this introductory chapter. However, a brief summary of some important works that have contributed to the development of the field are provided by way of introduction to visual information presentation.

The desire to represent our understanding of the world in a visual manner has been with us for a great length of time. The ancient human and animal representations in the caves of Lascaux (Figure 1.1 – 1), for instance, suggest a need for visual communication. They have been envisaged in popular culture

Figure 1.1 – 1
Cave painting at Lascaux
Source: http://astronomy.nmsu.edu/therriso/ast110/cavepaint.jpg
Accessed: 16th Nov 2010
as instructional aids to depict successful hunting strategies. However, as evidence for the intentions of these ancient artists is lacking, our introduction to the use of visual methods to inform must begin at a later date.

Early calendars such as the Aztec stone carving depicted in Figure 1.1 – 2 also seem to show a desire to show information visually, in whatever material is available to do so.

Many early languages make use of the visual representation of objects to communicate information. The hieroglyphics in Figure 1.1 – 3 represent objects in a clear, obvious manner. There are languages that still use these ideas of visual representation today. The Chinese/Japanese character that represents the word ‘tree’ looks like this: 木. The character for ‘wood’ (in the sense of a small forest) is two trees together: 林. The ‘forest’ character is three trees: 森. Likewise, the character for ‘root’ indicates the bottom part of the tree character: 本. The abstract, Roman letterforms used in English also have representative visual origins in many cases. The capital A,
for example, is supposed to have been derived from an ox’s head and turned upside down over the years (World Book Inc. 1992). Turned over, it can still be recognised, with its two horns and pointed nose: Π. Despite individual characters’ pictorial origins, the characters are now used in English in a completely abstract way, with no link to real objects. However, these abstract forms have sometimes been accompanied with more visual methods of communicating information over the years.

Maps have long been used to show a visual overview of information on the terrain and objects in the world. For example, the Mappa Mundi, created around 1300, is an example of an early ‘world map’ (Figure 1.1 – 4). It is a positional map, which could be used for explaining the locations of stories in
the Bible. It makes use of illustration, depicting famous people and events, which would make the map usable for the mostly illiterate audience of the time (Moir 1979). The concentric rings around the map show information about the 12 winds, showing which were supposed to bring storms, which were best for drying, and so on.

Edward Tufte, however, claims that, while mapping landscape is an ancient idea (Figure 1.1 – 5), the addition of data beyond positional is more recent (Tufte 2001). The map in Figure 1.1 – 6, from Japan, shows the number of passengers carried from place to place with the widths of the lines linking them. Such data maps can show relationships between observed data and the physical positions in which it is observed.
Introduction

1. Information graphics

1.1 When the ability to read and write was less common, visual presentations were sometimes used to transmit information and ideas. The woodcut in Figure 1.1 – 7 is an example of the use of an information graphic to show relationships in theological teachings (De Novo 2010).

An important development in the history of graphical presentation of information was Cartesian geometry, proposed by Descartes in the 17th century (Hartley 1960). The now widely used system of using the two (or more) Cartesian axes to represent space, enables points, lines and shapes to be described using mathematical equations. Therefore, it also offers a way of transforming numerical quantities into spatial positions, giving a visual presentation of numerical data.

William Playfair, a Scottish economist, was a great proponent of the visual display of numerical data (Tilling 1975). His work on displaying the relative value of imports and exports with early bar and time series charts has led to his accreditation as the originator of these kinds of graphics (see Figure 1.1 – 8).

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Figure 1.1 – 7
Medieval woodcut (16th century)

Source: http://blog.davidgolightly.net/?p=11
Accessed: 27th Dec 2010
There are also prominent historical examples of information graphics that have been used to present health data. A famous graphic, for example, was created by John Snow, to show data from the London cholera epidemic in 1854. He was sceptical of the dominant ‘miasma’ theory of cholera transmission, and used a data map (see Figure 1.1 – 9) to show how cholera cases centred around the Broad Street water pump (Newsom 2006). This information would be difficult to interpret as a long list of addresses, even if distances from the different water pumps were provided. The information graphic allows the viewer to quickly get a sense of the clustering of reported cholera cases and their relationship to the Broad Street water pump in the centre of the map.
Only a few years later, Florence Nightingale also made use of information graphics to present her theories on the importance of hygiene for military hospitals. Returning to Britain, after nursing soldiers in the Crimean War (1853–1856), she made recommendations on improving the poor sanitary conditions of the military hospitals in which she had worked. Her advice was initially not acted upon, until she produced her famous ‘rose diagrams’ (Brasseur 2005) (see Figure 1.1 – 10). This is an example of information graphics being used to persuade, as her intention was to convey a particular message. It seems clear in this instance that the information graphic was more persuasive than written, textual communication (Brasseur 2005). It may be that the viewer feels they can trust data that they can see for themselves, rather than relying on verbal rhetoric, or simply that the graphic has more impact in this instance.

Another famous information graphic was designed by Charles Joseph Minard, and published in 1869. This describes the disastrous loss of life through Napoleon's march to Moscow in 1812–1813 (see Figure 1.1 – 11). He uses a central bar to represent the journey of the army, gold showing the route to Moscow, and black the retreat. The central premise is that the thickness of this line is proportional to the number of remaining men in Napoleon's army. In this way, the graphic is able to show the army’s position, size, and direction of travel simultaneously. He also shows the rapidly declining temperatures on the return journey with a time series graph running from right to left below the main graphic. He is supposed to have said that these visual presentations were intended “less to express statistical results, better done by numbers, than to convey promptly to the eye the relation not given quickly by numbers requiring mental calculation” (Joyce 2008).
This technique of using bars with thickness proportional to a numerical quantity to show both flow and magnitude was also favoured by an engineer from Ireland, called Captain Matthew Henry Phineas Riall Sankey (1853–1925) (sankey-diagrams.com 2010). After retiring from his military engineering career, he worked on the efficiency of steam engines. In 1898, he sketched the energy efficiency of a steam engine in comparison to an ideal steam engine with no energy losses, using a proportional thickness technique similar to Minard’s. In Sankey’s application, the lines became arrows, and their thickness represents the energy flows of the steam engine (Figure 1.1 – 12).

Figure 1.1 – 12
Diagram by Captain Matthew Henry Phineas Rialll Sankey, showing the energy flows in a steam engine

(Schmidt 2006). Diagrams such as this are sometimes now referred to as Sankey diagrams in his honour. They are still used in engineering, and also in manufacturing to show resource flows (Figure 1.1 – 13).
Figure 1.1 – 13

The UK Textile Industry 1968-70

Information graphics are not always aimed at expert users. The Isotype Foundation, established by Otto and Marie Neurath, aimed to use visual presentation techniques for educational purposes (Neurath 1936). The work of the Neuraths and the other members of the foundation, from the 1920s to the 1960s, commonly used graphical presentation techniques to clearly explain simple statistical data. One such technique was to show numerical values using different quantities of simple symbols. In the Isotype diagram in Figure 1.1 – 14, each car symbol represents a certain number of cars produced in that year. The symbols used show what is being counted, making the graphic suitable for illiterate audiences, or those that speak a different language from the designer. The factories at the top of the diagram are not simply a decoration, but serve to give context to the viewer (Burke 2009). Many of the symbols themselves were designed by a talented symbol designer called Gerd Arntz (Annink & van Uitert 2008). These could explain to an illiterate audience, with minimal outside influence, what was represented by the different quantities (see Figure 1.1 – 15). Marie Neurath also produced leaflets with a health focus, aimed at preventing the spread of malaria in Nigeria (see Figure 1.1 – 16).

Figure 1.1 – 14
Otto Neurath – Car manufacture Isotype diagram.

Courtesy of Otto and Marie Neurath Isotype Collection, Department of Typography & Graphic Communication, University of Reading

Figure 1.1 – 15
Gerd Arntz’s symbols

Source: http://www.gerdarntz.org/
Accessed: 5th Dec 2010

Figure 1.1 – 16
Marie Neurath – Malaria information leaflet.

Courtesy of Otto and Marie Neurath Isotype Collection, Department of Typography & Graphic Communication, University of Reading
A very famous information graphic, designed to be used by the general public, was the London Underground map, first drawn by Harry Beck in 1931 (Garland 1994) (Figure 1.1 – 17). Beck realised that the passengers on the underground railway system did not need to know where stations were physically located. For them, the connections and order of stations was the only information that was required, which greatly simplified the maps. This technique is now used for underground rail systems around the world (Figure 1.1 – 18).
This same kind of knowledge of the audience for a piece of information design was demonstrated by the German graphic designer, Otl Aicher, in 1972. He and his team were commissioned to produce signage for the Olympic Games, in the stadium at Munich (Crabtree 2004). The challenge the team faced was that the audience for the Games came from around the world, understanding a wide range of different (verbal) languages. However, Aicher made use of the one common visual language he knew that they would all understand – the physical positioning of the athletes performing their events. The symbols that they designed to give wayfinding information to this international audience (Figure 1.1 – 19) were so successful that they have passed into public consciousness long after their intended period of use (アイデア (Idea) 2005).

A standard technique for the visual presentation of numerical data, easily recognised by statisticians to this day, was developed by John Tukey in the 1970s (Tukey 1977). He was interested in the presentation of sets of data, and recommended the use of ‘box-and-whisker’ diagrams, which show the minimum, lower quartile, median, upper quartile, and maximum value in a very recognisable form (see Figure 1.1 – 20). This has become a visual convention, used to present statistical data, which often needs no explanation for the intended audience (Cleveland 1988).

In recent decades, the development of computers has greatly expanded the scope for those wishing to present information in a visual form. The development and range of information graphics...
and visualisation has been revolutionised. It is now the work of a moment, for example, to use software like Open Office, Microsoft Excel or Apple Numbers to convert spreadsheet data into standard charts, not dissimilar to Playfair’s bar charts and time series graphs. The Google Charts API can be used to embed such charts in websites, based on dynamically generated data (Google 2010). It has become common to see these visual presentations in research articles, annual business reports and websites.

The computer has also enabled the creation of more complex visual presentations. A visit to the Information Visualisation conference in Europe (IV2011 2010), or VisWeek in the USA (VisWeek 2010), reveals hundreds of complex methods for showing many dimensions of data in visual forms. Websites like www.visualcomplexity.com and www.infosthetics.com catalogue hundreds of information graphics (see Figure 1.1 – 21).
One such complex, multi-dimensional graphical presentation is known as Gapminder (see Figure 1.1 – 22), which is similar to the ‘bubble charts’ available in many spreadsheet and statistics packages, but with the use of animation to see change over time. The Gapminder display has been made popular by Hans Rosling’s entertaining presentations (Figure 1.1 – 23). In one of these, he explains the complex relationships between GDP per capita and life expectancy in different countries, represented by the horizontal and vertical position of the circles. The size of the countries is shown by the size of the circles, and the region of the world using colours. With change over time shown using animation, this gives a total of five dimensions of data (gapminder.org 2010).

There are many software applications that have been developed to enable the creation of information graphics, sometimes referred to as ‘toolkits’. An example is ‘GAV’ (GeoAnalytics Visualization Framework) (Jern 2010a). Like many other visualisation toolkits, it enables several visual presentation techniques to be linked together, with changes in one affecting the others (known as a ‘multiple coordinated views’ or MCV technique) (Maciel et al. 2008). Several examples of the GAV framework in use are shown in Figure 1.1 – 24. This toolkit can be used to produce 2D maps, parallel coordinates, scatter plots, pseudo-3D maps, bubble charts, or time series graphs. One example of the GAV framework in use is the VISPER shipping data application described in Lundblad, Jern, & Forsell 2008. This uses a positional map ‘view’ to show shipping routes on a world map. A second ‘view’, called ‘list boxes’, shows categorical variables. Finally, a set of ‘parallel coordinates’ below shows several variables which may affect shipping times and cargo. This last
‘view’ represents each voyage as a line, which touches a series of vertical axes, each corresponding to a specific variable (as shown in the top-left ‘GAV components’ example in Figure 1.1 – 24). The three ‘views’ used in the VISPER application are linked, so it is possible to limit the data shown in various ways. For example, the map ‘view’ can be used to show only the data for one voyage, or a few selected voyages. The parallel coordinates view can be used to restrict the data shown to those shipments that were more than a day late, or between one and two days. In this way, data can be explored in a dynamic manner. This is just one application of the GAV framework, with others found in areas such as market research, radio network management, disaster management, or geovisual analytics (Jern 2010b).

Not all information graphics created with computers are so complex. The work of Nigel Holmes, for example, makes use of the power of computers to produce animated information graphics. However, these are very much aimed at a general public audience. He focuses on the use of wit, and entertaining delivery, to communicate his message (Holmes 2009) (see Figure 1.1 – 25).

Another currently practising information graphic designer is David McCandless, founder of the
Information is Beautiful website (McCandless, 2011), and author of the book of the same title (McCandless, 2010). While his background is in journalism, he has moved into creating information graphics. He often uses these to tell a visual ‘story’, aiming to help the viewer make sense of numerical data (see Figure 1.1 – 26).

Figure 1.1 – 26
The Billion Dollar-o-Gram by David McCandless
Accessed: 9th Sep 2011
David McCandless’ information graphics are aimed at a general public audience. Another example of this kind of use of an information graphic to engage attention and provide an entertaining way of understanding data is provided by a designer called Max Gadney (see Figure 1.1 – 27).

**Fighter Planes Get Faster and Deadlier**

![Fighter Planes Get Faster and Deadlier by Max Gadney](http://www.maxgadney.com/2008/10/wwii-fighter-plane-armament.html)

*Accessed:* 9th Sep 2011

Many information graphics have only a few pieces of numerical data, but some require many thousands. To facilitate the creation of more complex data-driven and interactive information graphics, the Processing language was developed at MIT by Ben Fry and Casey Reas in 2001 (Fry & Reas 2010). This programming language has been specifically developed to construct information graphics from numerical data. Its existence points to a need for the means to quickly and easily create new automated information graphic systems (Fry 2008).

The short history given above can only begin to show the enormous range of different possibilities for the visual presentation of information. It does, however, demonstrate how many different people, from all kinds of background, have been interested in the graphical presentation of information. Their ideas and creative talents have provided us with many possible ways of displaying data, giving visual information for different purposes and different audiences.
1.1.2 Approaches to understanding

Many writers, such as Chen (1999), Hammer (1995) and Spence (2007), begin from a starting point of assuming that graphical presentation of data is self-evidently important. They argue that, because information graphics are widely used, they must be valuable. Looking at some of the above figures, it is tempting to agree. They seem to have a way of explaining data that is very natural, and often appealing. In a scientific field like health technology assessment, however, we need to go somewhat further, and explore the specific purposes and qualities of information graphics, to be certain about the reasons for their use.

There is a recognition in some information graphics writing that it is only suitable to present some information visually. However, there is disagreement. Some say it is better to present complex data graphically (Hammer 1995; Remus 1987; Tufte 2001). Some say it is better to present numbers in tables when data is complex (Bertin 1981). Such disagreements about the appropriateness of information graphics may stem from their great variability in terms of the number of possible techniques, and the large number of different possible applications and audiences. As Tufte tells us, different graphics have different purposes (Tufte 2001). The function of the Neuraths’ Isotype diagrams was communication of statistical information to the illiterate masses (Neurath 1936). Sankey’s diagrams seem to be aimed more at expert users, with knowledge of the intricacies of steam power. Different graphics are aimed at different audiences, supporting different tasks, using different techniques. Thus, overarching statements on whether ‘information graphics’, ‘visualisations’ or ‘visual presentations’, as a whole, are more or less suitable for complex information, tend to oversimplify. Much depends on who the intended audience is, and what information is to be communicated.

With such great variability in purpose and techniques used for visual information display, it is difficult to make general propositions about where, when and why they should be used. What is clear, from the profusion of information graphics that have been produced over the years, is that there is an enduring attraction for the visual presentation of information, and a sense that it has a valuable role to play in communication and creating understanding. Literature in many different fields can offer explanations of why this is the case. These are not necessarily mutually exclusive, and can together be used to form an idea of the power of visual presentation of information.
1.1.2.1 **Approach 1: Physiological**

Some writers that offer work that is relevant to understanding information graphics take a physiological approach. Colin Ware’s books, for example, feature commentary on human visual capability and suggest ways that the designers of information graphics could respond to this (Ware, 2004). The writers Thomas and Cook draw on the physiological descriptions given by Resnikoff (Thomas & Cook 2005; Resnikoff 1989). Resnikoff has suggested that the human visual processing system is computationally powerful. He highlights the capabilities of the perceptual system, which is able to selectively process the large number of impulses recorded by the eye before information even reaches our brains. This idea of ‘visual pre-processing’ fits with the idea that graphical information presentation is able to make it easier to see patterns in complex data.

However, it is difficult to understand exactly how the brain interprets the electrical impulses that it receives through the visual system. Spoehr and Lehmkuhle suggest several different models that could be used to explain the brain’s interpretation of these impulses (Spoehr & Lehmkuhle 1982). They outline how visual processing can be understood in terms of ‘templates’, where the brain tries to match visual inputs to a store of previously experienced objects. They then suggest that the brain might instead class objects according to perceptual traits, recognising ‘prototypes’ for objects. This would mean that different levels of understanding were stored and matched, such as ‘blue’, ‘blue book’, ‘blue hardback book’. However, they then move on to an alternative view, called ‘feature models’, in which the brain interprets ‘elements’ of perception, making decisions based on which particular ‘demons’ are excited by visual stimulus.

When discussion of the physiological understanding of human visual processing reaches the level of the brain interpreting signals, there seem to be many possibilities and little conclusive evidence. While offering a potentially valuable line of enquiry, a physiological approach does not currently seem to offer enough certainty to be able to give conclusive recommendations on how information graphics should be used in particular application areas.

1.1.2.2 **Approach 2: Learning theory**

As the aim of information graphics is to inform, the process of using one to gain understanding can be thought of as learning. Therefore, learning theory offers an alternative approach. Several writers have different theories about ‘learning preferences’ (also known as ‘learning styles’). Kolb, for instance,
distinguishes between convergent, divergent, assimilating and accommodative learners, who each favour different parts of his ‘learning cycle’ (Kolb 1984). It is possible that people with different learning preferences might benefit more from graphical presentation than numerical or textual, but it is quite difficult to know which of these styles will benefit most. Interactive, screen-based graphics might allow the ‘active experimentation’ stage of the learning process to be strengthened, which might be expected to particularly benefit convergent and accommodative learners.

Other writers have suggested alternative theories to explain the different ways that people learn. Honey and Mumford distinguish between activists, reflectors, theorists and pragmatists (Honey & Mumford 1982). Entwhistle and Ramsden suggest four alternative styles (which they simply refer to as styles 1 to 4) (Entwhistle & Ramsden 1983). Butler has another four styles (styles A to D) (Butler 1987). It might be suggested that more active or independent styles could prefer the direct access to data provided by an information graphic over written summarisations. For some styles, the non-sequential quality of an information graphic might prove to be an advantage over the linearity of prose, allowing the viewer to reflect and explore. However, specific hypothesis generation is challenging, as these different possible categorisations of learning styles do not relate specifically to modes of information presentation, but rather to the activities engaged in by learners.

One learning preference categorisation that might provide a subgroup that would benefit more than others from information graphics is provided by the VARK website (Fleming 2010). The categorisation here is visual, audio, read-write and kinesthetic learning preferences. If some people prefer to learn in a ‘visual’ manner, they might favour information graphics over alternative presentations. This theory could be tested through empirical research.

1.1.2.3 Approach 3: Philosophical

There are also philosophical approaches to understanding information graphics. Rudolph Arnheim talks of there being no separation between visual perception and cognition (Arnheim 1969). This idea of “thinking with the eyes” seems to fit well with the way that information graphics generally work, enabling the viewer to see certain information more quickly and/or easily.

Merleau-Ponty’s *Phenomenology of Perception* provides a sophisticated philosophical view of experiential awareness (Merleau-Ponty 1962). However, like many philosophical writers, to understand much of his work a substantial
knowledge of the history of philosophical thought is required.

Philosophical understandings of information graphics might provide a rich discussion of the fundamental way they are perceived, but not offer the kind of practical advice that is aimed at in this thesis, for those interested in the design or use of information graphics in HTA.

1.1.2.4 Approach 4: Linguistic

Bertin takes a linguistic approach, and describes the use of ‘visual language’ (Bertin 1981). In a sense, in creating an information graphic, the designer is creating a temporary visual language, agreed with the viewer. The designer sets out which elements represent different kinds of data, often communicating this information in a key. They also make use of visual language conventions, such as the horizontal axis representing time, or box-and-whisker diagrams representing median, range, and quartiles of a data set.

This linguistic approach might link to Roman Jakobson’s (verbal) communication model, with the metalingual function (establishing whether the code being used is working) representing the information graphic’s key, for example (Jakobson 1980). Through this, an exploration of the semiotics of visual communication might be argued for as a useful approach.

1.1.2.5 Approach 5: Theoretical

Various theoretical views of visual perception are discussed at length in Gordon (2004). Such models often attempt to explain human visual processing through theories which account for optical illusions. These also have a bearing on information graphics, and can usefully give warnings for information designers.

However, the aim of this thesis is to directly inform the visual presentation of information in a particular scientific setting. Many of the above approaches to understanding information graphics could be used to inform information design activity. This might lead to strong and potentially useful information graphics. However, such investigations would say little about how information graphics can be used in the practice of health technology assessment. As the aim of this thesis is to have direct practical outputs, it focusses on how the functions of information graphics can be shown to contribute to the aims of health technology assessment, rather than attempting to formulate any kind of rules on how to understand them from a theoretical perspective.
1.1.2.6 Approach 6: Categorisation of techniques

On a more practical basis, other writers have focussed on the categorisation of different techniques, as standard tools that can be applied in different situations (Bertin 1981; Harris 1999; Lockwood 1969). Bertin, for example, describes four different specific ways of visually presenting data, that can be used for different kinds of decision-making. Harris describes many different kinds of graph, listing these alphabetically as a reference work for anyone that knows the name of a particular technique, and wants to see how to construct one. However, these texts do not provide the reader with any way of knowing how effective different presentation methods may be in a real context of use. This approach therefore seems at odds with those that argue that engaging the audience, by whatever means, is a primary concern (Holmes, 2009) and that measuring the information transmitted by a presentation is highly important (Sless, 2008). Also, it seems obvious from the many new media and platforms for information graphics being developed that while such categorisations of entire techniques may be a useful resource, they can never hope to be a complete record of all possibilities for information graphics.

1.1.2.7 Approach 7: Elements of design

Bertin also mentions that different information graphics can be created by combining visual ‘elements’, such as position, colour size, and others. These are used in place of, or in addition to, numerical values. Other writers have suggested a similar method, but each seems to have a different ‘list of elements’ on which to draw for creating their information graphics (Bertin 1981; Few 2006; Fisher 1982; Ware 2004). This also links to the foundations of the Isotype movement, in ‘transforming’ data into graphics (Macdonald-Ross & Waller 2000).

Looking at such subtly different lists of visual elements, it seems that designers have different ideas about the elements that can be used to create information graphics, which might start to explain why different designers produce different designs for the same brief (specification) (Brath 2008). This idea of creating information graphics from a set of visual communication elements will be returned to, in more detail, in Chapter 4.1 – Elements of information graphics.

The range of alternative sets of elements, that can all be used to design information graphics (as advocated by different writers), show the breadth of ideas on how to present information visually. With so many differing approaches to the design of information graphics, we might also expect
a number of different ways that people understand information graphics. However, there is some commonality between different people’s perception that we can draw on to communicate information visually. Two people shown a blue book are likely to both be able to agree on its fundamental visual properties. All sighted people have eyes that pick up light using similar (if not identical) bodily organs.

A designer can use an understanding of visual communication (whether philosophical, practical, physiological, or a combination of these) to make a set of assumptions, which are used to transmit information in graphical form. While professional design skills and tacit understanding should not be demeaned, this thesis largely deals with how these visual communication assumptions can be treated as testable hypotheses in a scientific context of use. In a field like health technology assessment, which will be introduced in Chapter 1.2, empirical research is a well-understood foundation of knowledge. Therefore the empirical effectiveness of information graphics might be expected to lead to acceptance and use of new techniques in the field.

1.1.3 Working definition for information graphics

This section works towards a definition of the term ‘information graphics’, which is provided towards the end of the section. Other terms might be used to describe the visual presentation of information. Terms such as ‘diagram’ or ‘chart’ are limiting, in that many of the information graphics presented in Chapter 1.1.1 would not fall within their remit. Likewise ‘data maps’ generally deal with describing something about physical space. Visual information presentations might be called ‘visualisations’, but as discussed later in this section, the term can be confusing when used in health research.

There are many different understandings of the term ‘information graphics’. Visual designers often have a different view to people with a background in computing, or television design, for example Wildbur (1989). For some, it is very much a science, with prescriptive rules governing what is ‘good’ and ‘bad’ presentation of information (Tufte 2001; Wilkinson 1999). For others it is more like an art, with the communication of a message the key, and personal approaches are important (Brath 2008; Fry 2008). A working definition will be used as a starting point for investigation of information graphics in health technology assessment.

It is tempting to consider information graphics as purely ways of displaying
Numerical data using visual elements. However, this definition is problematic.

The information graphic shown at the right of Figure 1.1 – 28 uses only photographs as the data source (shown to the left of the figure). While there is no numerical data involved, the graphic presents information on the use of the space over time. As it is a graphical information presentation, it might be called an information graphic.

Conversely, a table of numbers and text in a HTA report uses non-text, non-number objects such as grid lines to separate the data that is contained within. However, it would not be referred to as an information graphic, as it does not use any visual technique to provide information.

It is in some ways easier to discuss what is not an information graphic than what is. The alternative modes of communication in health technology assessment are through textual (in written reports), numerical (in data tables), and verbal communication (at committee meetings, for example). However, information graphics frequently contain both text and numbers, often for keys and labels, and also to directly present data. For example, a numerical value might be used to show what value area-based circles represent, thus giving an idea of scale relative to other diagrams.

Many information graphics transform numerical values into visual elements, such as the position or size of objects. However, a HTA ‘state transition diagram’, showing the possible treatment pathways of people in a treatment model, might contain no numerical data at all, but could be thought of as an information graphic.

Figure 1.1 – 28
Information graphic created from non-numerical data
Source: Von B und C (Hahn & Zimmerman, 2008)
In the exhibition shown in Figure 1.1 – 29, the smaller of the two piles has one grain of rice for each person that suffers from the HIV virus in the UK. The larger pile has one grain for each person living with HIV in sub-Saharan Africa (Stan’s Cafe 2010). This exhibit represents numerical data with the size (or rather count) of objects, but would not be called an information graphic. The word ‘graphic’ is strongly linked to ‘graph’, and as such suggests the virtual space of Cartesian geometry. It is also used in the term ‘graphic design’ to mean “a system of combining typography, photography, page layout and illustration to communicate information” (Livingston & Livingston 2003). Therefore, ‘graphic’ suggests reproducibility, in the virtual space of ink on page or pixels on screen, rather than one-off, real-world objects.

Under the working definition used in this thesis, information graphics in the context of health technology assessment are:

Reproducible presentations of information, which use graphical elements (e.g. position, colour, size, etc.) to present research data.
These graphical elements can be listed, but different designers of information graphics are likely to have different lists. These elements will be discussed in more detail in Chapter 4.1 – Elements of information graphics.

Information graphics are not like data tables, which present raw data, and do so using numerical values. They can, however, include textual, numerical, and even verbal elements. In Hans Rosling’s presentations for example, his verbal input is key to understanding the data presented. For a graphic to give information, the communication aspect is crucial. Data is not information until it informs someone – or potentially informs them, as an information designer cannot always control how their work is in fact interpreted, and readers come with different levels of experience and ability. This use of graphical elements, aimed at providing understanding, is a defining aspect of an information graphic.

The term ‘information design’ has already been used for at least 30 years at the time of writing. In 1978, the famous London design agency Pentagram separated information design into: systems (a kind of design style guide), posters (for advertising), packaging, promotion (such as leaflets, calendars and annual reports) and exhibitions (Crosby et al. 1978), none of which would correspond with our working definition of information graphics. Their use of the term in fact covered all of graphic design. At the same time, the Information Design Journal was founded, which expanded the term ‘information design’ to cover the use of language as well as graphical information (Information Design Association, 2011).

Information graphics could be described within the area talked of by Easterby and Zwaga in their book Information Design (Easterby & Zwaga 1984). However, they mention that “it [information display] is ... a comprehensively difficult topic to grasp in its entirety”. Their use of the term ‘information design’ also encompasses signage and wayfinding/wayshowing, and instructional materials, as well as the kind of visual presentation of data that is of interest to us here.

The Thames and Hudson Dictionary of Graphic Design and Designers defines ‘information graphic design’ as:

Generic term applied to those graphic design projects required to communicate complex data to a specific range of audiences. The detailed analysis of user needs that underpins successful information graphic design differs from the more subjective approach applied to
projects aimed at selling a product. (Livingstone & Livingstone 2003)

They also mention that such projects might include “major signage schemes, health and safety issues, public services and technical manuals”, which largely fall outside the definition of information graphics used here.

The meaning of ‘information design’ used here is that of the *Information Design Journal* (Information Design Association, 2011), which focusses the term on functional communications only, effectively excluding persuasive motives.

While information graphics can be thought of as the products of information design, they could instead equally be defined within the field of ‘information visualisation’. This field is familiar with the idea of communicating the message revealed by data (Firebaugh 1993). In the field of health, however, the term ‘visualisation’ is often used to refer to virtual representations of the body for medical training and imaging of health conditions, which are not included in the working definition of the term ‘information graphics’ used here.

Information visualisation also encompasses visual data mining and clustering algorithms, which are not necessarily information graphics in that they do not inform themselves. Although a clustering algorithm might be used to group objects which do communicate information using graphical elements, the algorithm itself is not an information graphic, while it is the visualisation of numerical data.

The special case of ‘state transition diagrams,* which are often used in health technology assessment reports, could be described as the products of information design and as information graphics, but not information visualisation, as they do not present numerical data. Information graphics are therefore found within information design, but not all of them would be called information visualisation. Many information graphics would also be considered information visualisation, as they visually present numerical data (see Figure 1.1 – 30).

It should be noted that there may, or may not be, products of information design that are also information visualisations, but not information graphics (the light purple area on the diagram). As these would be outside the working definition of information graphics used in the thesis, they are not important to the discussion here.

* used in HTA to show the treatment pathways that can be taken by the people in a mathematical model.
Whether or not information design and information visualisation should be separate, they represent different traditions. Information visualisation is an inherent and central part of many sciences, but is often performed without reference to the skills and traditions of professional graphic designers. Information design, on the other hand, tends to focus on emotional impact and attracting attention, rather than the degree of precision that is essential in a scientific context. The research detailed in this thesis is an attempt to combine the skills of design professionals with the scientific rigour necessary for the use of information graphics in the field of health technology assessment.
1.2 HTA (health technology assessment)

1.2.1 A brief history

A comprehensive history of health technology assessment (HTA) is beyond the scope of this thesis. Excellent and detailed histories can be found in Banta (2003), O’Donnell et al. (2009) and Szczepura & Kankaanpää (1996). However, as this thesis may be relevant to those working principally in information design, a brief history of health technology assessment is provided by way of introduction to those unfamiliar with the field.

The origins of the word medicine are in the Latin ‘ars medicina’, or ‘art of healing’. However, Tore Scherstén writes in his foreword to Assessment of Health Care Technologies (Szczepura & Kankaanpää 1996) that the ‘art of medicine’ has become more like a ‘science of medicine’. Over the years, it has developed to the point at which providing empirical evidence of the benefits of medicine is key (Sackett 1996).

For a drug, medical device, or surgical procedure to be licensed for use in the UK, it must be approved by the Medicines and Healthcare products Regulatory Authority (MHRA 2010) or the European Medicines Agency (EMA 2010). In either case, empirical evidence of the efficacy of the drug must be given before it can be used by health professionals in the UK health system. Like many other health systems around the world (Fricke & Dauben 2009), this process provides a legal framework, which indicates which drugs, devices and procedures are safe to use. However, proving efficacy (the performance of the health technology in the idealised situation of experimental conditions) is only the first part of the process.

The idea of using scientific evidence to determine which treatments can be used owes much to the development of ‘evidence-based medicine’. The movement’s “Philosophical origins extend back to mid-19th century Paris and earlier” (Sackett 1996). Evidence-based medicine aims to make the best possible use of empirical studies to inform medical practice, in terms of individual patient decisions (Banta 2003).

Health research is performed to provide evidence on the efficacy or effectiveness of many different ways of improving health. These can be
curative ‘treatments’ such as drugs and surgical procedures, but also screening programmes and public health interventions, designed to detect or prevent health problems. For this reason, the word ‘intervention’ is often preferred to the term ‘treatment’ when talking about the objects of health research.

In clinical trials, the ‘gold standard’ of empirical study is the randomised controlled trial (RCT) (Schulz 1997). The essential idea of the RCT is to give different interventions to different groups of people. In this kind of study, people from an overall set of recruited participants are randomly assigned to groups. Randomisation is vital, as it can not only account for known confounders,* but also unknown ones (Schulz 1997). Once different groups have been randomly generated, statistical techniques can then be used to determine the relative efficacy of the different interventions. In many RCTs, particularly those dealing with drugs, such interventions are often tested against an indistinguishable, but inert ‘placebo’. This is vitally important as the psychological effects of taking a placebo intervention can lead to observable differences from those that are given no medical attention at all.

However, with the increasing numbers of interventions licensed, it can be difficult for health professionals to keep abreast of the volume of published empirical evidence. In 1996, Sackett reports that a general practitioner would have to read 19 articles a day, 365 days a year, to keep their knowledge completely up to date (Sackett 1996). That rate may have increased substantially since then. An important step towards addressing this problem was the creation of an organisation called the Cochrane Collaboration, which opened its first ‘Cochrane Centre’ in 1992 (The Cochrane Collaboration 2010). The organisation aims to “assemble an updated register of all randomised controlled trials” (Banta 2003). This allows RCTs and reviews of multiple RCTs to be brought together, and searched in a systematic manner.

The Cochrane Collaboration, and other such databases of scientific evidence, have enabled the development of a technique called ‘systematic review’ (Egger, Smith, & Altman 2001). This technique involves searching databases for relevant evidence, with predefined criteria for which papers will be included and excluded from the review. The resulting papers can then be collectively analysed to provide an overview of what that pool of evidence generally shows. This is one of the fundamental parts of health technology assessment in the UK (Banta 2003).

The phrase ‘health technology assessment’ became used in the 1970s, by the Office of Technology Assessment in the USA (Szczepura & Kankaanpää 1996).
Advances in technology had led to very expensive equipment being used, such as the CT scanner (computed tomography scanner). The first health-related report produced by the Office of Technology Assessment “examined the effects of public and private policies on the development, diffusion, use, and reimbursement of CT scanners” (Office of Technology Assessment 1978) (see Figure 1.2 – 1). It seems that some idea of how these technologies were being used in practice (how ‘effective’ they were) was needed, as opposed to just how well they worked in experimental conditions (‘efficacy’).

It should be noted that the word ‘technology’ in the term ‘health technology assessment’ refers to a broad category of interventions (not just medical equipment and devices). The definition of a ‘health technology’ includes: “The drugs, devices, and medical and surgical procedures used in medical care, and the organizational and supportive systems within which such care is provided” (Office of Technology Assessment 1978).

The Office of Technology Assessment continued its work for 23 years, but was eventually closed in 1995, because of “controversy over the content of several of its reports and political pressure from the commercial health technology industries” (Sullivan et al. 2010). Publicly funded health technology assessment work in the USA is now carried out to a limited degree by various different organisations, but is largely held as a commercial asset by health reimbursement agencies (Sullivan et al. 2010).

However, even after the closure of the OTA, HTA activity continued to grow around the world, particularly in countries with ‘universal’ health care such as Canada (Menon & Stafsinski 2009), Australia (Bulfone, Younie, & Carter 2009) and many European countries (Drummond & Sorenson 2009; Fricke & Dauben 2009). It began to take on the functions of not only discussing the efficacy, effectiveness, and social and ethical acceptability of health interventions, but also looking at their costs (both financial and societal), and their cost-effectiveness (Eddy 2009).

Fundamentally, HTA assesses not just the effectiveness of health interventions in practice, but also the costs and cost-effectiveness of long-term use in a particular health system (Szczepura & Kankaanpää 1996). Proponents of HTA methods say that this allows limited health resources to be distributed fairly
across a health service, with only the better value for money interventions being approved for use.

To do so, uncertainty within the evidence must be considered. Often, for instance, an intervention might be expected to give benefits for a longer period of time than that covered by the trial data available. For this reason, sophisticated mathematical modelling techniques are commonly used to predict what the costs and benefits of adopting an intervention would be over the lifetime of people receiving that intervention.

The INAHTA organisation (International Network of Agencies for Health Technology Assessment) was established in 1993, to coordinate the limited resources for HTA work internationally (INAHTA 2010).

At a similar time, a project was set up to begin to draw European HTA activity together, leading to the EUR-ASSESS report, published in 1997 (Banta 1997). This report was a joint work of HTA producers throughout the region, written in response to rising health care costs in Europe from the 1960s onward. The report gave recommendations for giving timely information on health technologies, in a form useful to the intended audience. It took some of the recommendations of the OTA, and showed how they could be used in Europe. The ECHTA/ECahi project between 1999–2001 was then able to begin the process of coordinating HTA activities in Europe (Institute of Technology Assessment (Germany) 2001).

HTA now has its own international society called HTAi (Health Technology Assessment international). This society boasts members in 59 countries and six continents, and organises annual international conferences. Relevant HTA research is published in its official journal, the International Journal of Technology Assessment in Health Care (HTAi 2010).

The work of HTAi is supported by the International Society for Pharmacoeconomics and Outcomes Research (ISPOR), which publishes the Value in Health and ISPOR Connections journals. These offer methodological and technical articles that support the work of HTA around the world.

More recently, the EUNETHTA project, running from 2006 to 2008, helped to develop further HTA collaboration in Europe (EUNETHTA 2010). This has led to the formation of the EUNETHTA Collaboration, which aims to support HTA work in EU countries.
1.2.2 Focus: NICE appraisals

HTA work around the world can vary as much as health systems of the countries in which it is performed (Banta 2003). This thesis uses the work of NICE, the National Institute for Health and Clinical Excellence in the UK as a focus. This organisation is an established example of the interface between HTA and health policy, and is considered a well-developed health technology assessment system (Eddy 2009).

NICE was established in 1999, to use the results of HTAs to provide guidance for the NHS on the use of the technologies assessed (Drummond & Sorenson 2009). The NICE process is described in *Health Technology Assessment in England: Assessment and Appraisal* (Walley 2007). In summary, the process begins with HTA topics, provided by the UK’s Secretary of State for health in association with the NICE secretariat. These are fed to a group called the HTA programme, based at Southampton University. This group commissions a document called a ‘technology assessment report’ (TAR), which is produced by one of several university-based technology assessment centres, often in consultation with clinicians and NHS managers. The reports are advisory in nature, and do not explicitly make a recommendation to NICE (Stevens & Milne 2004). The evidence from this report is considered at an appraisal committee meeting, alongside evidence submitted by the technology’s manufacturers, patient groups and other interested parties (Drummond & Sorenson 2009).

The volume of evidence submitted can be very large, and decision-makers have limited time to consider it. A participant in a study in Chapter 6 of this thesis mentioned that they had recently been given 1,200 pages of evidence to read in one week before an appraisal, on top of their regular working commitments.

One defining aspect of the HTA system in the UK is that a distinction has developed between supposedly objective, scientific ‘assessment’ of evidence, and ‘appraisal’, “which is value based judgement … consider[ing the] ethical, organisational, political and social impact of technologies” (Gabbay & Walley 2006). Other countries incorporate these value-based judgements into assessment work, but in the UK this is the explicit role of NICE (Woods 2002).

Currently, the NICE guidance which results from this process determines which technologies are recommended for patient treatment within the UK’s National Health Service (NHS). However, at the time of writing in 2010, due to a new government’s election, a move is being made to ‘value-based pricing’.
In such a system, the results of appraisals like these are supposed to affect how much the NHS is willing to pay for a technology, according to the benefits it delivers (Claxton et al. 2008).

### 1.2.3 Stakeholders

Many different groups of people are affected by the decisions made by nice. Patients that can or cannot receive an intervention due to the decision made are an obvious and important stakeholder group. Manufacturers of a technology involved in an appraisal are also affected, in financial terms. NHS managers also have a stake in the decision, as it is they that will have to decide what other costs to cut within their limited budgets for each new technology approved by nice. As the general public have an interest in the decisions, so too do news providers and other media organisations. Researchers at other institutions around the world can use nice HTA reports, which are available freely both on the nice website (National Institute for Health and Clinical Excellence 2009) and that of the UK’s National Institute for Health Research (NIHR) HTA Programme (NIHR Health Technology Assessment Programme 2010).

Any and all of these interested parties could potentially benefit from the understanding provided by graphical information presentations. Indeed, one purpose of the HTA Programme in the UK is to communicate such research to a wide audience (Gabbay et al. 2001). However, it has been noted that “the chief audience for TARS – as for other HTA reports – is ... decision-makers” (Milne, Clegg, & Stevens 2003). Many of the other stakeholders, while interested in the data presented, are ultimately affected by the committee members’ decisions. For this reason, the nice committee members, and those that work to inform their decisions, are the main focus of the research detailed in this thesis.

Frønsdal writes that: “…it is essential to identify the key decision-makers at the outset of an HTA, consider what evidence they need to inform their decisions, [and] in what form that evidence should be provided...” (Frønsdal 2010). As the form in which the presentation of evidence is shown to decision-makers is an essential consideration, research on effective graphical presentation of this evidence could potentially be greatly beneficial to the process.
1.2.4 Working definition of HTA

Health technology assessment activities differ greatly throughout the world. As each health system is part of the historical and cultural traditions of a country (Banta 2003), the needs and purposes of HTA can vary. In some countries, such as the UK, HTA activities have a strong emphasis on assessing effectiveness, costs and cost-effectiveness of interventions (Drummond & Sorenson 2009).

HTAi defines HTA as “…a scientifically based and multidisciplinary means of informing decision-making regarding the introduction of effective innovations and the efficient use of resources in health care” (HTAi 2010). Informing the decision-making process is a key aspect of this definition. The summarisation and communication of evidence can be a useful way of thinking about HTA, from the point of view of research into the use of information graphics in the field.

HTA, then, is functionally defined for the thesis as:

The use of scientific evidence to inform health policy-making in terms of recommendations for the adoption of specific health interventions.

This scientific evidence might be formally conducted RCTs, registers of patient data from health providers, or knowledge elicitation from experts (which can be essential if published evidence is lacking). The key aspect is that this (often uncertain) evidence must be assembled together, and presented to inform policy decisions. The thesis focusses on the potential use of information graphics in technology assessment reports (TARs) produced to inform the NICE appraisal process in the UK. The data presented in these reports are used as they can be shown to directly affect policy decisions, and therefore meet the definition of HTA used here.

The relationship of HTA to EBM can be a useful way of explaining this definition. Evidence-based medicine can be envisaged as the use of scientific evidence to inform the use of medical interventions for the treatment of individual patients. This might be using published studies to help decide which of a number of different drugs to prescribe for a person, or whether to opt for a surgical intervention. HTA is the use of this same pool of available evidence to inform health policy. In the case of NICE, this decision is at a national level, although larger countries such as Canada take many decisions at a provincial or regional level (Menon & Stafinski 2009). These policies (national, system-wide decisions) describe the area in which EBM (individual patient decisions)
can operate, after excluding interventions that are not cost-effective or not sufficiently well-proven to be used.

This description of HTA in relation to EBM is shown in Figure 1.2 – 2.

**Figure 1.2 – 2**
Relationship of health technology assessment (HTA) and evidence-based medicine (EBM).
1.3 Potential functions

There are many potential functions for information graphics, presented in a diverse range of literature. Card talks of their usefulness in ‘amplifying cognition’ with ‘increased resources’, ‘reduced search’, ‘enhanced recognition of patterns’, ‘perceptual inference’, ‘perceptual monitoring’ and providing a ‘manipulable medium’ (Card, Mackinlay, & Shneiderman 1999). The Card text is very much situated in the data visualisation field, and many of these potential functions relate to complex data presentations, which can be automatically generated by computers.

In the context of HTA, where printed reports are the principal mode of delivery for information graphics, a different list of potential functions is appropriate. These will be used to focus many of the research studies in the rest of the thesis:

1) Presenting complex data (Remus, 1984; Remus, 1987)

2) Condensing data into a small space (Tufte 2001)

3) Comparison and overview of multivariate data (Spence 2007)

4) Enabling faster information processing (Resnikoff, 1989)

5) Selective focussing (Thomas, 2005)

These functions are used to support the search for user needs in HTA, and as the basis for the design of new information graphics in the field. While there may be other useful functions that information graphics may perform, such as attracting attention, the use of a small list provides a way of managing the needs assessment. However, care has been taken in all studies not to ignore other possible functions of information graphics.

1.3.1 Potential function 1: Presenting complex data

Two companion papers by Remus (Remus 1984; Remus 1987) show that the complexity of the decision environment can affect the effectiveness of different presentation methods. Remus’ graphical presentation did not perform well in the decision environment in his initial 1984 paper. However, when he
incorporated a more complex decision environment in his 1987 experiment, the graphical presentation method was much more effective. Therefore, if there is an area of HTA which is perceived to involve complex numerical data, it may be beneficial to attempt to present it using a graphical technique.

1.3.2 Potential function 2: Condensing data into a small space

Edward Tufte’s *The Visual Display of Quantitative Information* (Tufte 2001) explains at length how graphical information presentations can display a large amount of data in a relatively small space (see particularly Chapter 8: ‘Data density and small multiples’). He explains that in some (but not all) cases, graphical techniques can be economical in terms of space, presenting more information than numerical or textual displays in a given area of a page or screen.

1.3.3 Potential function 3: Overview and comparison of multivariate data

Spence’s (2007) *Information Visualization* details how graphical methods can be used to assist in decision-making, particularly for problems involving multivariate data. There are many possible ways of presenting such data, but where comparisons need to be drawn between two or more pieces of information to assist in decision-making, information graphics may play a useful role.

1.3.4 Potential function 4: Enabling faster information processing

Resnikoff’s (1989) *The Illusion of Reality* suggests that the link from our eyes to our brain allows large amounts of data to be communicated to us in an efficient manner. Much information is ‘preprocessed’ without us having to provide conscious input. Judging distances and relative sizes is something that we spend great effort on throughout our early lives (Merleau-Ponty 1962). If there are situations in the HTA process where information must be absorbed in a time-limited situation, a graphical display may be appropriate.
1.3.5 Potential function 5: Selective focussing

One of the advantages of presenting information in interactive displays is that the user can select which information they see (Thomas, 2005). This is not unique to graphical presentations, as textual lists can be hidden or expanded on-screen without the use of visual elements. However, visual display techniques allow, for example, certain information in a display to be picked out in a certain colour. Even without colour, grouping elements together, or linking them can allow for selective focussing.

The use of information graphics, therefore, allows more sophisticated selective focussing, even when an interactive presentation is not available. In cases where data is overwhelmingly complex, this may be very useful. If there is information in reports that is presented in amalgamated form, it might prove useful to decision-makers to see only small parts of it at a time. Research is necessary to determine whether this is the case.
1.4 Problem domain

Information graphics are used in many different fields, and there are some kinds of graphic that may be more or less appropriate in HTA than other areas. This section aims to clarify which aspects of the use of information graphics in HTA the thesis addresses.

There is very little guidance on the use of information graphics available to those that author technology assessment reports in the UK. The most up-to-date NICE guidance document on producing these reports recommends the use of two specific graphical presentation techniques (forest plots and cost-effectiveness acceptability curves – see Chapter 3.1 for more information) (National Institute for Clinical Excellence 2004). However, it does not make any other recommendations on how to present data, and where and when other graphical methods would be appropriate.

Some writers, in other fields, can begin their discussion with the assumption that, since graphical information presentation is quite common, information graphics must therefore be useful (Chen 1999; Hammer 1995; Spence 2007). There is evidence that, in general: “We are visual creatures, and are good at noting relative differences in sizes, lengths, orientations, and other visually perceptible properties” (Hill & Milner 2003). As such, it might be argued that presenting information visually might be a useful way of providing information in health research. However, the designers at Pentagram note that “Diagrammatic pictures can often convey information more rapidly and precisely than verbal instruction. They can also be more imaginative, or at least prettier, than is perhaps altogether necessary for practical purposes.” (Crosby, Fletcher, Forbes, Grange, Herron, Kurlansky, & McConnell 1978). In the politically charged environment of HTA, decisions are potentially life-changing for some stakeholders. As such, we need to explicitly show why and when they are useful.

As an example, one of the potential functions of information graphics, that is highly valuable in commercial and news media, is to engage attention. As Otto Neurath said, “to remember simplified pictures is better than to forget accurate figures” (Burke 2009). In HTA, however, the decision-maker is already motivated to understand information. It has been suggested that, in pharmacoeconomic modelling in general, “we should give absolute priority to accuracy [over transparency]” (Eddy 2006). The accurate and clear
presentation of information is the aim, rather than the engaging, witty graphics produced by Holmes, McCandless or Gadney (See Chapter 1.1). These would be suitable in news media, where attracting attention is an essential part of the graphic’s function. However, as informing policy is the central goal of HTA activity, information must be presented in a form that is helpful and useful to a policy decision-maker. The aim is to improve accessibility without affecting accuracy in any way.

There are several questions that must be addressed by research before we can know how to work with information graphics in HTA.

1.4.1 Defining information needs

The aim of this thesis is to work towards graphical presentations that assist HTA’s function of informing health policy decisions. To do this, the first research requirement is to establish what visual information presentation methods are currently used. This will show which information is and is not currently presented using information graphics, and therefore which HTA data could be most suitable for research into alternative presentations.

Information graphics can have a number of different functions. Bertin notes that: “cartography with several factors depends a) on the level of information being sought and b) on the point in processing: research or communication” (Bertin 1981). He argues that different graphics are suitable for different uses. This suggests that a clear idea of what is needed will be essential to be able to make the most important design decisions when creating an information graphic.

It is therefore useful to know more about what information HTA decision-makers need, and if there are any data that they currently have difficulty in interpreting. Research which establishes information needs might also suggest whether interactive graphics might be useful, in which the decision-maker plays some part in manipulating the data shown.

Information graphics have potential disadvantages as well as advantages. For example, displaying two very similar values in a bar chart might make it difficult to see which of the two is greater. In some applications, this might actually be beneficial, as it would emphasise how close the two values are. In other areas even minute differences might be important. Research into user needs will also be able to show how important accuracy is to a decision-maker.
HTA work can produce a very large amount of information. Care will have to be taken that information graphics are used that can alleviate, rather than compound the sense of “information overload” that was a problem in HTA in 1997 (Banta 1997). Due to the increasing numbers of clinical trials published in the intervening time (Sackett 1996), this problem is likely to be even more acute at the time of writing. Information needs assessment research might be a good opportunity to discover which parts of HTA data are very complex. This will enable the design of information graphics to take account of information overload.

1.4.2 Design and production

There are several different ways in which information graphics could be produced in HTA. While it might be argued that the availability of existing tools should not constrain the presentation of information, the existing production processes and distribution methods in the field may also be able to convey some information quite effectively. It is also likely that different production methods will be more appropriate for the various different kinds of data that are presented in HTA reports.

One approach would be to use standard tools to present data visually, such as the bar charts and line graphs produced by Open Office, Microsoft Excel and Apple Numbers. These have the advantage of being quick and easy to produce as well as readily understood. However, this approach might not lead to the most useful graphics from the decision-maker’s point of view. As Ben Fry observes, “Any bar chart or scatter plot made with Excel will look like a bar chart or scatter plot made with Excel” (Fry 2008). The visualisation techniques available in such software is of course limited in what it can produce. While they may be suitable for producing some of Playfair’s bar charts, or applying Descartes’ ideas on the Cartesian axes, they cannot at the time of writing be used to create a complex Sankey diagram or data map.

As an alternative to these standard tools, specialist software is used in HTA to produce specialist graphical displays such as forest plots (see Chapter 4.2.8.1). New software might be designed that can turn commonly used HTA data into specific visual representations. If the necessary resources for developing these tools could be found, they might provide a way for research teams to provide specific information graphics on a regular basis. However, if some HTA data
by nature has complexities that are specific to individual interventions, this approach might not be worth the investment in creating such tools.

If HTA data has intervention-specific complexities and patterns, it might be more appropriate to design information graphics on an individual basis. An information designer, employed either by the teams producing reports, or based centrally at a commissioning body, would be able to react to situations arising on a case-by-case basis. While this approach might be desirable in situations of great individual variation between interventions, it has the disadvantage (over a specialist software approach) of requiring a longer production time, and depends on the availability of specialist visual layout skills and software. Also, if a one-off presentation technique was used that was unfamiliar to the reader, they might have to spend some time learning to interpret the graphic. Some visual conventions used in information graphics (such as the appearance of a box-and-whisker diagram) may already be understood by an audience. Others will have to be explained by the graphic’s designer, or be shared by other users of the graphics. This is another reason for the importance of empirical evaluation of information graphics – to better understand the knowledge and capabilities of the audience for an information graphic.

1.4.3 Evaluation

Testing is an integral part of designing information graphics. Bertin tells us that “Whenever several characteristics are to be superimposed, the least bad representation depends above all on the distribution of the characteristics. There is only one solution: undertake several trials” (Bertin 1981). His meaning of ‘trial’ is in the sense of ‘trial and error’ – he is encouraging the designer to create several versions of a display to find out which one they feel works best. He argues that good visual representations can only be created through personal experimentation.

This kind of self-evaluation is essential, and will be a familiar process to information designers. In HTA, however, providing understanding of information to decision-makers is an integral part of the process. Where information graphic techniques and principles are to be used routinely in HTA to support this goal, they can be tested in terms of what information they impart to their audience, and whether they impart it more accurately or more quickly than other methods. However, the evaluation of information graphics can be challenging. Similar graphical techniques can be more or less
useful in different contexts (Remus 1987). Graphics that are condemned by participants in an evaluation can perform quantitatively better than seemingly more favoured alternatives (Elting et al. 1999). Also, it may be that different people respond more to graphical presentation than others, or that taste plays a role in whether an information graphic is rated favourably or not. Therefore evaluation studies must be careful to ask “What does it mean?” rather than “Do you like it?”

Evaluation studies of information graphics performed in information design frequently use small samples of people, and are quite informal (Frascara & Ruecker 2007; Jackson et al. 2003; Tekušová & Schreck 2008). Some financial and medical information graphics are tested with large-scale quantitative tests (Feldman-Stewart, Brundage, & Zotov 2007; Frownfelter-Lohrke 1998). There are some studies that fall between these two kinds in size, which use both quantitative and qualitative methods (Sless 2009; Wright, Belt, & John 2003). Care should be taken that appropriate experimental designs are used to evaluate information graphics in HTA. Only then will it be possible to show that information graphics can be used, in practice, to effectively give understanding to decision-makers. This will be discussed at greater length in Chapter 2 – Methodology.

**1.4.4 Media**

Information graphics can be distributed in a number of ways. The presentation media used necessarily affect the possibilities in terms of display resolution, quality, the use of interactivity and animation, and so on.

Information graphics could be included in HTA reports, which are frequently distributed in printed and electronic form. When printed, HTA reports are usually limited to black ink on white paper, which might limit the techniques that can be used. Coloured graphics would have to be demonstrably more useful than black ink only to justify higher printing costs. This is not such an issue with electronically distributed documents. However, the standard Microsoft Word and Adobe PDF formats that tend to be used for electronic distribution limit the possibilities for information graphics in terms of interaction and animation. HTA information graphics might, however, be presented online, which would mean that interactive or time-based graphics could be used.

While information graphics can be used to present numerical data, they
would not replace numerical presentation in reports entirely. It is important for future research to be able to use data reported by systematic reviews and mathematical models. However, they may be able to replace numerical presentation of data in the main body of reports, if it can be shown that they can offer things that numerical presentation cannot. The literature is unclear on which kinds of data should be presented in numerical format. Bertin suggests that numerical presentation is better in complex situations (Bertin 1981), while Tufte maintains that the reverse is true (Tufte 2001). Individual testing may provide evidence for the most appropriate forms of data representation in the specific context of HTA reports.

As mentioned in Chapter 1.2.2, technology assessment (objective presentation of data) is separated from appraisal (value-based judgment) in the UK health system (Gabbay & Walley 2006). Information graphics used in TAR reports should therefore inform the NICE appraisal process, but must be used to show objectively what messages exist in data, rather than to persuade. This is a difficult balance to strike. While the temptation when producing an HTA report may be to include all data, to avoid any kind of bias, raw data is problematic to interpret without careful arrangement by an analyst (Ehrenberg, 1975). Thus, the role of choosing the data to present most prominently, to enable the reader to understand it, is an important and responsible one – as is choosing the most appropriate methods of presenting it visually. This person is referred to in Otto and Marie Neurath’s Isotype system as a “transformer” (McDonald-Ross, 2000). In HTA, the transformer may be the same researcher preparing technology assessment reports, an analyst presenting these to the decision-makers, or (potentially) a visual communication specialist.
The central research question, to be addressed by the rest of this volume is as follows:

*How should information graphics be designed, produced and used in health technology assessment?*

The three parts of this question take on board many of the problems mentioned in Chapter 1.4, and aim to provide a useful basis for understanding the structure of this research:

**Design:** Firstly, the successful design of information graphics involves establishing information needs, developing prototype tools, and evaluating their effectiveness. This process is shown by example, beginning in Chapter 3. This chapter details two studies, used to establish the current use of information graphics and information needs in HTA. Chapter 4 describes an approach to the design and development of information graphics that embodies these needs. Chapters 5 and 6 show how such information graphics can be evaluated and how this evaluation can inform the design process. Together, these chapters give an account of each stage in the choice and design of two information graphics for use in HTA.

**Production:** The second part of this question deals with how such prototypes could be produced in practice. This depends on the lessons learned through the research studies, particularly on how much the volume and complexity of information in different technology assessments. The information needs study (in Chapter 3.2 – Information needs) is particularly important to this, but the results of Chapters 5 and 6 (Prototype tests 1 and 2) also have a bearing on the question. The concluding chapter, 7 – Discussion, responds to these findings, detailing the different ways that information graphics can be produced for inclusion in future reports, as a part of the authoring process.

**Use:** The last part of the question is to address how information graphics perform in practice. The research study in Chapter 3.1 details some of the techniques used, but as these tend to be limited to standard graphing techniques, which have already been discussed in some detail elsewhere (Cleveland 1984). For the somewhat more elaborate techniques detailed in this thesis, information on how they will be used must currently be inferred
from the experimental studies in Chapters 5 and 6. These have limitations in terms of addressing the actual use of information graphics in decision-making. Additionally, some anecdotal evidence of the use of one of the new information graphics is provided in Chapter 7 – Discussion, which also describes the effectiveness of information graphics in real use rather than experimental conditions. This might be addressed in future research studies.