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Working memory and background knowledge

Cognitive science in the design classroom

Abstract

This article discusses two universal principles from cognitive psychology, and proposes some ways in which those principles relate to graphic design. The two most important principles are first, the strict constraints of working memory, a function which persists for only a few seconds, and second, the finding that perceptions and meanings are mediated by the cultural knowledge of viewers, including their knowledge of design conventions and genre. Better designs are likely to emerge from the designer's familiarity with these psychological and cultural principles. Visual examples, including maps and student projects, illustrate how the two principles are useful for classroom instruction.

Keywords: working memory, context, background knowledge, visual narrative, teaching

Introduction

Much exciting research has been conducted in cognitive science since George Miller (1956) published his path-breaking article, 'The magical number seven, plus or minus two: Some limits on our capacity for processing information'. Building on Miller's observations, Alan Baddeley (2014) has developed a robust model of working memory — or 'temporary storage system' — that aims to explain such memory processes.[1]

Some art-theorists, especially the great art historian Ernst Gombrich (1960), have invoked the findings of psychology in analysing the effects of art, but his insights came a few decades too early to invoke the powerful limitations of working memory. These developments in cognitive science, which validate Gombrich's historical perspective, have largely been missing in graphic design teaching, which is still dependent on theories of structuralism and semiotics that were pervasive in the 1970s and 1980s.

Structuralism and semiotics, founded on the ideas of the brilliant Swiss linguist Ferdinand de Saussure (1959), have since gone out of fashion, except perhaps in graphic design. In *Semiology of Graphics*, the imposing book on maps, networks and diagrams by the French cartographer Jacques Bertin (2011, p. 419), 'graphics' is dogmatically presented as a 'monosemic' system (one sign = one meaning) in a synoptic table that includes other systems, such as music and mathematics. The recently published comprehensive textbook, *Graphic Design Theory*, by the respected author Meredith Davis (2012), includes many visual examples explicated in the tradition of structuralism and semiotics.

This article, through maps, diagrams and visualizations, attempts to broaden the aim of design teaching in the classroom to include principles of cognitive science, especially those related to working memory. The article will also describe design strategies aimed at mitigating the strict time limitations of this universal memory bottleneck, which lasts only a few seconds.

Can a graphic be universal?

Are there universal principles that determine good graphics? If the question is taken as meaning 'Is there a universal practical recipe for creating good graphics?' the answer is 'no' because of the cultural contingency of any given graphic with respect to any given viewer. The visual form of an image is contingent upon its meaning as interpreted by an audience, as the great iconologists Panofsky (1962) and Gombrich (1960) have shown. Background knowledge is always required to make sense of even purely formal inputs. The false belief in

universal trans-historical forms is called 'The Myth of the Given' (Sellars, 1956). The given is a myth because every form we perceive is 'post-interpretatum' (Cleveland & McGill, 1984; Casner & Larkin, 1989; Carpenter & Shah, 1998; Cook, 2006; Canham & Hegarty, 2010; Hinze et al., 2013).

Ernst Gombrich rejected as groundless the idea that certain concrete design elements will appeal to all audiences at all times and places; the very form of the design element is never a brute given, never unambiguously *there*, but rather a psychological construct, that is, something co-constructed by viewers from their prior knowledge and expectations. Gombrich made the point very succinctly in explaining the naiveté of scientists who placed a graphic design in the Pioneer Spacecraft, which was meant to communicate something about human civilization for the benefit of beings in outer space, who undoubtedly would lack knowledge not only of the represented objects but also of our conventions of representation (Gombrich, 1982, p. 150-151). For instance, the right side of the woman's face is narrower than her left (Figure 1). What sort of lopsided creature is that?

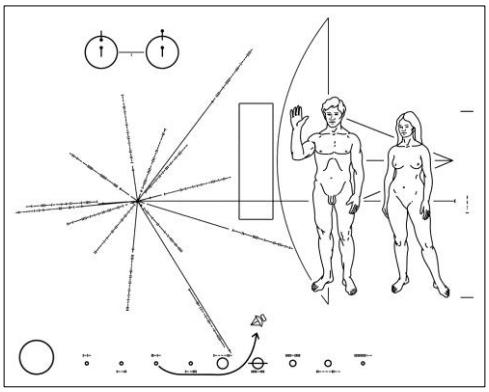

Figure 1. A golden plate with this design was included in the Pioneer 10 Spacecraft launched by NASA in 1972. Design by Carl Sagan, Frank Drake, and Linda Salzman Sagan. Dim. 23 x 15 cm (9 x 6 inches) Wikimedia Commons, public domain, 2013.

However, if one asks the more modest question 'Are there universal principles that determine good, culturally contingent graphics?', then recent cognitive psychology has much to tell us.

In describing their work, graphic design students and professionals use form, texture, colour and so on to combine functionality with aesthetics. A graphic design work — 'graphic' for short — is successful when it achieves both its communication goal and a certain aesthetic level. Although beauty and functionality are both important, graphic design students are taught that functionality comes first. The main function of graphic design is to communicate, and we cannot escape the old dictum that form follows function. In addition to the formal elements of layout, typography, colour, and so on, which are the core of both teaching and practice, what psychological principles enable a graphic to communicate successfully? Recent studies in cognitive psychology indicated that universal principles are indeed involved in the perception of a graphic and that these are always at work in both successful and unsuccessful communications. The principles hold for both verbal and visual experiences, that is, for a book, a poster or a webpage. Proper knowledge of these cognitive principles can help the designer to construct successful visual solutions.

Cognition (1): The time constraint of working memory

In the interaction between the graphic and the viewer, a very important psychological principle is the time limitation set by working memory, which lasts only a few seconds. 'Working

memory' is the name given by cognitivists to the short time span during which the human mind can put experiences together to form a meaning that is lodged in long-term memory. Understanding this very stringent limitation or bottleneck of the mind is one of the greatest insights of psychology since 1956, when Miller published his famous article on the 'magical number seven'. The current view sees the limitation as mainly a time constraint, a window of just a few seconds. Within those first few seconds, if the viewer is not able to 'construct' the various elements into a broader meaningful whole that is sent to long-term memory, then some will quickly drop from working memory, and little that is meaningful will survive.

Because of this limitation of working memory, a good designer tries to reduce the viewer's processing time. Within the window of the viewer's working memory, a meaningful whole must emerge from the various elements. The viewer can repeat the process for various subgroups of elements, but in every case has to reach meaningful closure. A similar sub-process takes place in language, where the clause, which is considered the primary unit of speech, is a universal feature of all languages (Hirsch, 1977, p. 108-109). However, unlike in a written text, in a graphic, the primary units need not be perceived in a fixed, specific sequence. For example, a good transportation map works well as a meaningful overall image, but its more practical use is in obtaining local, detailed step-by-step instructions that are related to some sub-portion of the whole, such as a specific route or a specific neighbourhood.

Thus, in order for the viewer to be able to reach fast closure within a few seconds, the designer has to make the elements of the graphic work quickly in concert. However, this time limitation need not apply to the whole graphic at the same time. As a good book, or a beautiful speech, can successfully communicate to the reader or listener through a succession of well-defined primary units, such as clauses and other sub-units, a good graphic can be comprehended as a series of meaningful visual units that have reached 'closure', each of which is comprised of several smaller component elements.

However, despite the universality and transcultural character of these psychological constraints and because of the various settings in which graphics can be used in a practical way, individual graphic design problems require individual, ad-hoc solutions. Thus, a theory of graphic design is not a fixed set of universal *formal* principles, but instead must be the flexible adaptation of cultural and psychological constraints — especially the universal limitation of human working memory.

Chunking

The concept of closure is closely tied to that of 'chunking'. Miller found that a chunk can be as discrete as a single digit, but it can also collapse multiple items into a single new item (Miller, 1956). He explained that although one can never keep more than about seven 'chunks' of information in immediate memory at the same time, if one can chunk the items, such as the digits in one's social security number (i.e., the tax number in the United States) then one can remember that number more readily. Hence, social security numbers are written in chunked groups, such as 434-65-9623. This example has nine digits but only three chunks, making the number much easier to handle and recall than 4-3-4-6-5-9-6-2-3. These simple chunks can represent extremely complex meanings. An explicit concept, such as a word, a name or a phrase, always represents a much larger set of implicit meanings with which the reader may be more or less familiar, such as the name James Bond (Hirsch, 1977, p. 124).

Cognition (2): The verbal, visual and spatial components of working memory

Almost twenty years after Miller's 'magical number seven', Baddeley and Hitch (1974) proposed the multi-component model of working memory. The model has undergone many refinements since 1974 but it remains the standard reference in cognitive psychology on working memory (Baddeley, 2014).

Baddeley's model of working memory includes two important components. One is the articulatory or *phonological loop*, which provides temporary verbal storage, even in the case of visually presented materials. He found that we unconsciously name objects as they are presented to us, in a process called 'sub-vocalization', which is a kind of inner speech (Baddeley 2014, p. 49-66). Since the 1970s, it has been known that we subvocalize when viewing pictures (Noizet & Pynte, 1976). Such naming plays a strong role for gaining rapid closure in the successful perception of a visual organization, just as it does in the understanding of a verbal organization (Logie, 1996).

Another component of the model is the *visuo-spatial sketchpad*, which is involved in the temporary retention of visual and spatial information. According to Logie (1996, p. 53), 'As the phonological loop has been linked to the speech system, the visuo-spatial sketchpad has been linked to the control and production of physical movement'.

The tight visual-verbal interaction that takes place in the process of working memory suggests that the effort is distributed among all the components of the system, especially between the phonological loop and the visuo-spatial sketchpad. Therein lies a key point for designers: either with or without text in the design, the role of the verbal seems just as important as the visual in processing visual information! Moreover, the *quick recognition of representations is connected with the quick naming of them,* which can be reinforced by the extensive use of text in graphic design. Designers should be aware of the universality of subvocalization. The silent act of looking at pictures is accompanied by the activity of inner speech, just as silent reading is (Baddeley, 2014).

Cognition (3): Background knowledge and familiarity

Until the viewer interprets the graphic, it has no meaning. The formal features of any design do not precede but follow the interpretation of that form. In the interpretation process, the viewer brings to bear a complex system of expectations comprised of prior experiences. Hence, the second universal principle is that the viewer constructs meaning based on external stimuli that are made meaningful by prior experience. Modern psychology holds that perceiving and remembering are both productive acts based on previous experience — an important insight that psychology has reconfirmed many times since the path-breaking book by F. C. Bartlett: *Remembering: a study in experimental and social psychology* (1932). Bartlett included the idea of socially shared expectations as part of the remembered event. The art of creating an effective graphic involves the designer's successful social prediction of the kind of response a typical viewer will probably construct. Memory is not the passive reproduction of past events but is an active productive process. Similarly, the experience of the graphic is not passive but a productive activity that is based on the viewer's relevant experiences.

The two principles of working memory and the collaborative co-construction of meaning always interact. In communication, if the viewer is familiar with the subject matter, closure will occur much faster. Therefore, it is important for the designer to include in the graphic the most appropriate and relevant information, instead of assuming that the viewer already has this information. The limitations of working memory can be reduced greatly if the background knowledge of the viewer is both highly familiar and relevant to the subject matter at hand.

Words, not just pictures

Although the temporal limitation of working memory cannot be influenced directly, the designer can provide the necessary 'scaffolding' — an array of visual and verbal aids — for the viewer to build on her or his existing knowledge. Graphics seldom consist of only text or pictures although the latter are more likely to need words than vice versa. It is often true that a

picture is worth a thousand words, but sometimes a graphic that does not provide enough textual support runs the risk of being misunderstood and misinterpreted. In the interplay between the image and the text in a graphic, this task of providing enough textual information is often neglected, although the addition of text to the visual elements can make the graphic truly informative. Amanda Cox, graphics editor of *The New York Times*, stresses the importance of the 'annotation layer' — the written text — in successful data visualization. She stated, 'We learn by connecting to what we already know' (Cox, 2012). She proved her point with a simple exercise performed on the front page of *The New York Times* (paper edition), in which she highlighted things that she did not already know. The extent of facts unknown by her amounted to only about 10 per cent per day, during a typical week (Figure 2).

Figure 2. Front page of *The New York Times* from 18 September 2012, detail. The highlighting shows new knowledge acquired that day. Replica of original exercise presented by Amanda Cox. Author's collection.

Most graphic constructions, however sophisticated, are therefore dependent and highly influenced by the relevant background knowledge of the viewer. New knowledge is best communicated by a graphic that combines new elements with familiar elements of the past. Brief notes, legends and captions are thus an excellent way to provide the viewer with background knowledge upon which new knowledge can be built.

This annotation technique was shown to work effectively in a student graphic about gas prices (Figure 3), which was inspired by an article in *The New York Times* about the changing price of crude oil (Mouahad, Cox, & Nguyen, 2008). The graphic depicts the fluctuation of gas prices (vertical axis) as well as total consumption (horizontal axis) in the United States between 1979 and 2012. In the graphic, a line connects various dots representing the years from 1979 to 2012. The position of each dot plots the price per gallon and total consumption for that year. The line appears to move backwards when consumption dropped after 1979, 1988, and 2007.

Various points on the line are annotated with small chunks of text. The economy of means of this graph — clean lines and legible typography, combined with concise and clear text — make for a well-sequenced and informative piece. All visual and verbal elements provide for fast closure, and although the data are relatively complex, the viewer is able to absorb the parts and quickly move from the overview to the detailed description.

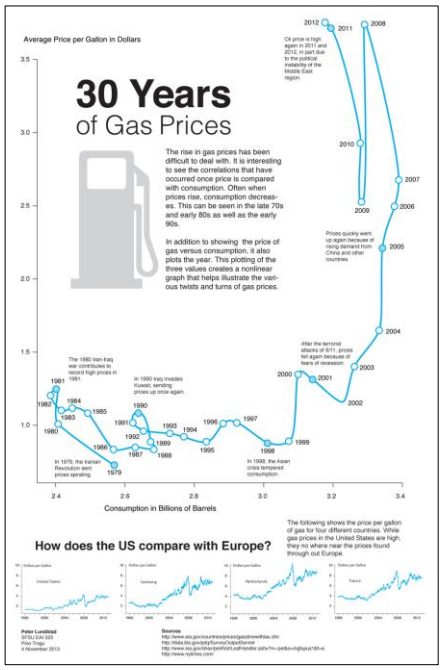

Figure 3. Thirty years of gas prices. Poster size: 11 x 17 inches. Source: Student work by P. L., 2013.

Conventions, context and genre

Design conventions play a critical role in the exchange between the designer and the viewer. Similar to the set of conventions in spoken and written languages, design has a set of visual conventions. It is a mistake to assume that the viewer will be automatically familiar with the design conventions that the designer employs. However, because all verbal and visual communication is based on prior agreement with a set of conventions, an effective designer works within the constraints of the conventions that are familiar in a given cultural moment. A visual element that might mean one thing in Europe might mean something completely different in Australia.

Anthropology has shown that although black may have a negative value and white a positive one in one tribe, the reverse may be the case in another tribe; the same may hold for numerous design elements. No doubt, some elements are trans-cultural, such as the female body and an infant's face, but the safest course is to assume that all design elements are dependent for their effectiveness on the culturally constituted assumptions and expectations of the viewers.

As Bartlett pointed out, the act of remembering, as well as perceiving, is not the mere reproduction of a previous experience, but instead a re-construction based on typical features of other events of the same type experienced over time. When looking at the front page of a newspaper, for example (Figure 4), we prepare to read it based on how we read it in previous instances. We expect to see titles at the top and text immediately below them. We expect all the columns of text under a title to belong to the same article, and so on. These expectations, if properly fulfilled, contribute to the re-construction of the object, 'newspaper', as we know it. We recognize the object newspaper as belonging to a similar type, or 'genre', as we have experienced it in the past. The recognition of genre takes place within the narrow window of working memory lasting just a few seconds, and the positive feedback regarding an object that matches our previous experience of similar objects, enables us to move forward to read the articles in the paper.

Imagine a situation in which the visual elements and the typographic conventions of titles, subtitles and so on were disrupted or omitted. Imagine that the articles have no titles.

Looking at this unfamiliar object, the typical reader of *The New York Times* would be puzzled and wonder if he or she were holding a real copy of the paper or a fake one. He or she would not recognize the paper, based on prior experiences. The genre and type would not be determined within the first few seconds, and communication therefore would be compromised. Genre and type are not absolutes, however, but function within the social conventions of a given cultural time. This is the social dimension and perception pointed out by Bartlett: the viewer must share in the system of values and conventions within the specific historical context if he or she is to understand the specific genre and types presented at that given moment.


The New York Times

Hard Charger At Obama Side Has Hands Full

ANOTHER DELAY FOR HEALTH LAW AS SNAGS PERSIST

No Pecan Pie? Thank China, Rain and Pigs

Democrats See a Palin Legacy They Can Like

An Unlikely Role in Alaska Fight on Oil Taxes

Figure 4. Front page of *The New York Times*, detail. California edition, 28 November 2013. Author's collection.

One of the first readers of *The New York Times*, which started publication on 18 September 1851, might be forgiven for feeling disoriented if he or she travelled forward in time more than 150 years and were given a copy of the same paper in 2015. What would he or she make of the extensive use of relatively large titles, subtitles, and above all, coloured pictures? He or she would have been familiar with newspapers that densely pack text, use minimal titles and display no pictures at all. The first issue of the paper (Figure 5), which was originally named *New York Daily Times*, employed exactly these graphic conventions, which were typical of the genre of newspaper publishing at the time of its debut in the middle of nineteenth-century America.


New-York Daily Times.

Figure 5. Front page of the *New York Daily Times,* detail. Later renamed *The New York Times*. First issue, 18 September 1851. Wikimedia Commons, public domain, 2015.

The example of *The New York Times* demonstrates that one of the most important tasks for the graphic designer is to make sure to include the elements that help a viewer quickly place the object in the right context, that is, to identify immediately the correct genre or type. Only after the type or genre is identified can the reader start making meaningful constructions and making sense of the whole. What type of graphic are we looking at? If this question is not answered within the first few seconds of the interaction, the viewer will have trouble focusing his or her attention on the piece. That window sometimes can be reopened and the viewer will need to 'restart', but more often than not, he or she will become frustrated and refocus his or her attention on something else. The designer needs to not only provide the elements necessary for correctly identifying the genre but also *exclude* elements that might be misleading and steer the viewer in the wrong direction. Because visual elements and verbal text are not absolutes but vary in the meanings they convey and therefore are ambiguous, the designer must eliminate this ambiguity immediately at the high level of titles, subtitles and large images. Effective titles and other means of quick orientation to type or genre are necessary in any graphic, in order to keep the reader's attention. Proper initial orientation — quickly identifying the genre — is akin to the role played in a good map by the You-Are-Here mark, which helps in pointing out one's position on the map. The mark quickly establishes the spatial relation of the viewer to his surroundings. In a graphic, the elements that properly identify the type or genre help the viewer to place quickly that graphic into the larger, correct social context.

Within the very first few seconds, proper orientation is central to further understanding, but this orientation and further understanding are dependent both on the time limitations of working memory as well as existing background knowledge. One way to help the viewer 'keep up' is to include in the graphic many elements that are already familiar to the viewer, elements that are part of the viewer's existing background knowledge.

A beautiful design that did not work

How does the duality of working memory and background knowledge affect a graphic? When the New York City Transit Authority introduced it in 1972, the striking map of the subway system shown in Figure 6 was radically different from previous ones. Maybe too different! Just seven years later, after complaints from confused subway riders, it was discontinued and a new map issued, with a more traditional design that has survived to the present day virtually unchanged (Lloyd & Ovenden, 2012).

Figure 6. New York City subway map, detail, 1972. Massimo Vignelli, designer. Revised: February 1978. Dim: 45 x 56 cm (18 x 22 inches), MTA, 1978. Author's collection.

Despite its beauty, the discontinued map — by the late Italian designer Massimo Vignelli — was very problematic for the average user. In a case of false parallelism between simplicity of form and simplicity of communication, the arbitrary geometry of its square format actually works against the physical observations of the subway rider who could not easily match the stretched distances and distorted proportions of the map with the reality and the precise topography of the city above the ground.

By contrast here (Figure 7) is its more complex replacement, which, with modest changes, has satisfied subway riders for the past 36 years:

Figure 7. New York City subway map, 1979. Michael Hertz, designer. Revised: Summer 1985. Dim: 58 x 71 cm (23 x 28 inches), MTA, 1985. Author's collection.

Today's New York subway map is the fruit of many refinements, but the underlying structure has remained intact since the 1979 edition (Figure 7). It is an analogical representation of the network of train lines superimposed upon the familiar structure of New York's streets, parks and rivers. Vignelli's map (Figure 6) showed few details beyond those pertaining to the subway system. However, the replacement map includes all kinds of information: above-ground train lines, tunnels, parks, streets, airports, cemeteries — things belonging to the real world, which the average user is trying to navigate. Complexity of representation translates into simplicity of communication, while Vignelli's simplifications translated into psychological super-complexity that exceeded the limitations of working memory.

However, ask a three-year-old from a small rural town which of these two pictures she prefers, and the answer might well be the abstract Vignelli — depending on whether she likes straight lines rather than curves.

There is a further subtlety: there is no principled reason why a schematic representation that was executed sensitively could not have worked. One could very well make one's way in New York using a schematic map, just as one does in London, where the Underground has a similar schematic, which like Vignelli's map, emphasizes the rail system rather than the underlying topography (Figure 8).

Figure 8. London Underground tube map, detail. Transport for London, 2007. Author's collection.

The London map, which essentially reproduces Harry Beck's original design of 1931 (Wikipedia, 2015), has endured for 84 years and is still in use today. Why then did the abstract schematic in London succeed, whereas Vignelli's failed? We know that a schematic, topographically incorrect map has continued to work for tens of millions of passengers in London. Why did Vignelli's map not work? A reasonable explanation is that because London is a river city surrounded by land, one needs only a schematic representation of the defining river to achieve orientation in real space. If the land area depicted is lengthened or fore-shortened here and there to magnify the busy centre, as in Vignelli's map, the schematic of the river still enables one's orientation in space.

The myth of simultaneity

Another example of misguided parallelism with geographic maps is graphics that mimic traditional road maps in order to show relationships within an abstract system. However, while traditional maps bear a direct, natural connection to the physical objects that they represent, such as roads, cities, rivers and so on, in these diagrams the subject matter is often a set of abstract concepts that lack a given natural arrangement. The 'mind map' or 'concept map', popularized by Joseph Novak and Bob Gowin (1984) in their book *Learning how to learn,* is thus analogous to a road map. However, in a road map, the amount of information is usually not a factor, whereas in concept maps, the absolute limit of the number of items on which one can focus at any given time (Miller, 1956), as well as the stringent time limitation of working memory, play against the insights gained by a simultaneous spatial arrangement. Instead of remembering and retrieving the concepts, the viewer tends to retain only the visual abstract image, without retaining the concepts or the main content.

Concept maps also exhibit another crucial defect, which was first pointed out by Ferdinand de Saussure — the confusion between *langue* and *parole* (Saussure, 1959). *Parole* refers to the actual utterances we make, such as sentences with (explicit or implied) subjects and predicates. *Langue* is the entire shared mental convention system of a speech community at any point in time, which enables *parole* to be spoken, written and understood. His distinction between *langue* and *parole* was path breaking and illuminating: *langue* is a system of possibilities, and *parole* is the realization of some of these possibilities in actual usage. Most concept maps miss or ignore Saussure's epochal distinction: sentences, not individual words, are the basic building blocks of speech. In these concept maps, we are left with a vague visual representation of *langue*, but no *parole*, that is, no real speech. We are given individual words, similar to those in one of those magnetic poetry sets, but the words alone simply do not communicate. The connections supposedly afforded by the spatial arrangement

of concept maps, that is, the various possible *paroles* (many possible paths) remain in the abstract area of shared possibilities, that is, all *langue* and no *parole*, all commercials and no programme.

The sceptical reader might try to learn and remember the content of Figure 9, which shows a typical concept map produced by a student for an information design exercise now discontinued.

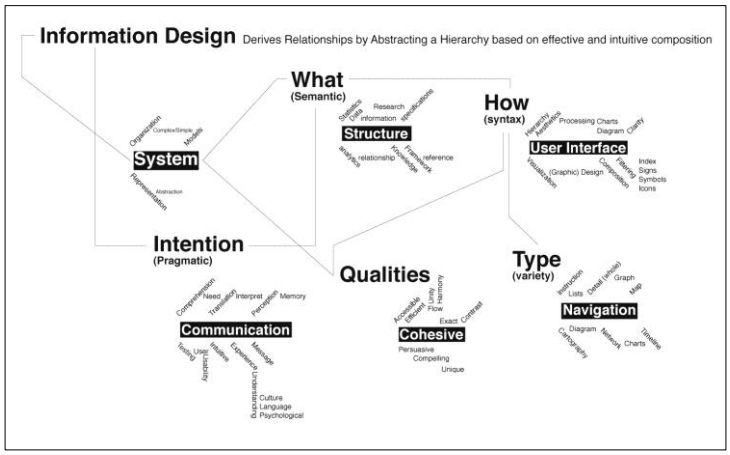

Figure 9. A concept map of key elements in information design. Source: Student work by K. K., 2009.

The road map model was adopted in a recent typographic illustration in Time magazine showing the 2012 London Olympics (Cooke et al., 2012). In this example (Figure 10), there is no attempt to assign specific meaning to the colourful lines containing the text. The lines are simply there to evoke the lines of the London underground map, if one has seen it before. It is up to the reader to read all the zigzagging text crammed inside the coloured lines, without getting a stiff neck.

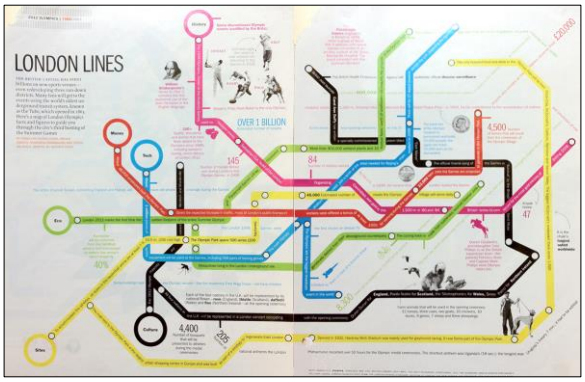

Figure 10. London lines. Article and infographic on the 2012 London Olympics. Time magazine, 30 July 2012. Spread size: 16 x 10.5 inches. Author's collection.

In the same issue, another illustration of Olympic trivia (Adams et al., 2012), while still rather crowded, manages to do a much better job of breaking down the information into smaller, finite chunks of text that can be read more easily and sequentially (Figure 11).

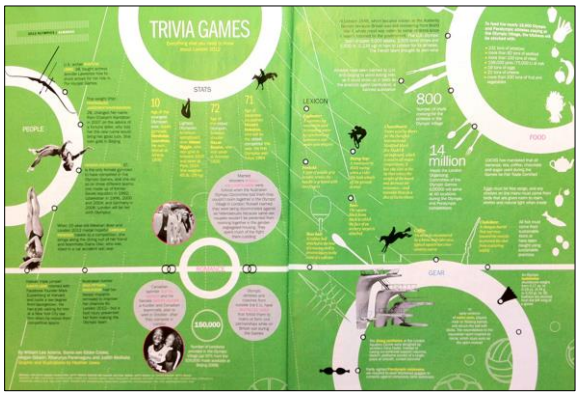

Figure 11. Trivia games. Article and graphic in Time magazine, 30 July 2012. Spread size: 16 x 10.5 inches. Author's collection.

Cognition in the design classroom

The current explosion in the use of infographics and data visualization tools has had a strong effect on today's students of design, but how does one distinguish good infographics from bad? For example, which of the two representations of quantity shown in Fig. 12 would be processed faster by the viewer?

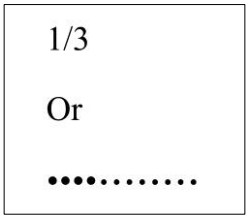

Figure 12. Which symbol better represents 'one third'? A numerical fraction or a series of dots?

Today, many popular infographics use the repetition of little dots or icons to represent numbers, which is an unfortunate distortion of the isotype system developed by the Austrian polymath Otto Neurath (2010) and his associates. However, George Miller's fundamental insight was that the limitations of working memory could be overcome by chunking, in which several things are unified into a single thing, thus reducing the number of elements the mind has to deal with at the same time. Hence, as shown in Figure 12, 1/3 is a chunked version of the little dots **.....** . Although brilliant, Neurath's isotype system is not always optimal. When used with discretion, it need not crowd out working memory, and it may work well. If Neurath, who was highly alert to the trends of philosophy and psychology, had lived in the era of cognitive psychology, he would have surely accommodated his ideas to it.

The little dots in effect unchunk the fraction. Some designers, who misapprehend that dots, because they are visual, are processed simultaneously, show an unfortunate tendency to reverse Miller's insight and unchunk a unitary idea into multiple elements, thereby increasing processing time.

The two examples shown in Figure 13 are details from student work that was influenced by the Neurath-derived trend of using little people and little squares to represent quantities, and worse, proportions. However, we no longer use pebbles to count. It is much better to write out the number or to visualize it using a single solid area, as in a simple bar chart or pie chart, instead of many tiny areas in repeated little rows.

Figure 13. Representations of quantitative data that use repeated little people or dots invert Miller's principle of 'chunking', thereby increasing the cognitive load on the viewer. Source: Student work by J. L. and T. B., 2011.

A comparison of two posters: baseball and skyscrapers

Two posters by students in my information design class will help to clarify Miller's principle of 'chunking'. The first poster (poster #1, Figure 14) addresses the topic of team payrolls in major league baseball in the United States. The second poster (poster #2, Figure 15) represents the topic of the world's tallest buildings.

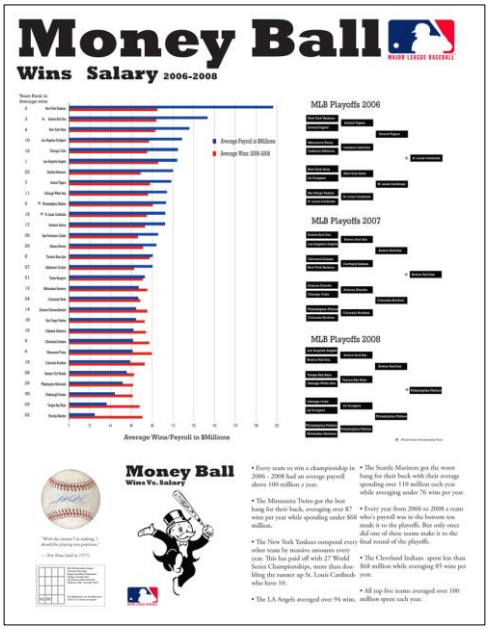

Figure 14. Student poster #1 on the relationship between payroll and performance of teams in major league baseball from 2006 to 2008. Poster size: 34 x 44 inches. Source: Student work by A. N., 2010.

Poster #1, like poster #2, starts with a big title at the top, but the title in poster #1 requires more background knowledge than the title in poster #2 does. 'Money Ball' refers to a book and the movie by the same title, which are about the Oakland Athletics, a team that advanced to the playoffs and almost made it to the World Series, despite its minimal payroll budget. However, viewers who are not familiar with the book or the movie are unlikely to make that connection. In poster #2, the title means exactly what it says. If the viewer of poster #1 is not familiar with the baseball world, then the title is an obstacle to the viewer's apprehension.

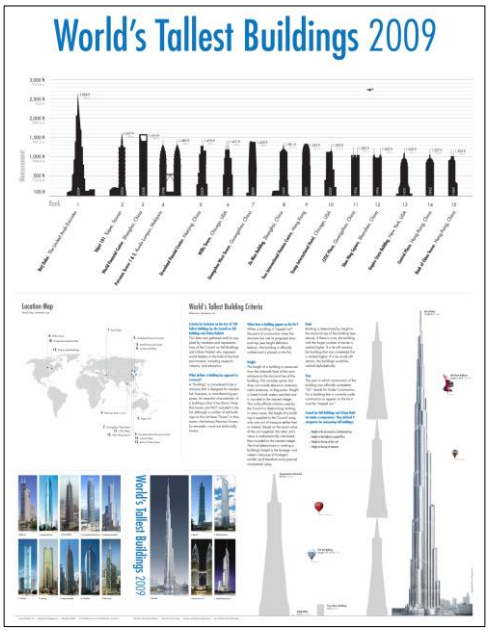

Figure 15. Student poster #2 on the world's tallest buildings in 2009. Poster size: 34 x 44 inches. Source: Student work by M. L., 2010.

Below the title, both posters present large graphics, one depicting the relative salaries and performance of baseball teams, from 2006 to 2008, and the other showing the 15 tallest buildings in the world in 2009. Poster #1 also includes playoff brackets from 2006 to 2008. Additional pictures and text are included in the lower portion of both posters. As usual, in these examples, the viewer needs to assess quickly the genre if his or her attention is to be retained long enough to proceed to the smaller, localized elements of images, text, maps, graphs, photos and so on.

However, the viewer of poster #1 will be off to a very slow start, for the majority of the poster's layout consists of two separate, visually very active graphs, only one of which provides directly relevant information. The bar chart disproportionately occupies most of the space although it provides limited information. The graphic brackets showing the playoff pairings offer no information about payroll or performance. The bar chart on the left does include relevant data, but the display is too busy because of the colour vibration, and thus poster #1 struggles to convey its message by failing to provide easily 'chunkable' groups.

In contrast, the layout of poster #2 provides a series of well-defined chunks. First is the clear, descriptive title. Next is the large graphic showing a pictorial bar chart of skyscrapers with detailed information about height, rank and so on. The world map then shows the location of each building. In the middle of the poster, the explanatory text offers a short but detailed introduction to the material, and below that is a diagram of the tallest building compared to another smaller, well-known building, which indicates the huge scale involved. Finally, the photographs of the buildings provide the most direct visual presentation of the material.

In short, every element, especially the title and the large graphic, contributes to capturing and focusing the viewer's attention and retaining it in the precious initial seconds allowed by working memory. All the elements fulfil the expectations of the viewer by adhering to the visual schemes experienced earlier. The large graphic resembles a giant bar chart, the world map is clear, and the text is well arranged, with clear subtitles and concise paragraphs. The diagram with the stacked skyscrapers follows a familiar comparison device, and the familiar display of photos and captions completes this informative piece.

Poster #2 then seems to satisfy the constraints of working memory by giving a quick snapshot of the topic, then by guiding the viewer through the smaller visual units or chunks.

Conclusion

The visual is temporal. A common mistake in graphic design is to assume that the visual elements of a graphic are atemporal and that the design problem is solved with a handsome arrangement and clear elements. From the viewer's standpoint, however, the visual design is a time-dependent interpretive problem to be solved within the constraints of working memory. It is not an immediate experience. It is mediated, and its elements are likely to be unclear unless great care has been taken to enable closure to occur rapidly, causing the present perceptual experience to be transferred to the permanent storage of long-term memory, which is the repository of all successful communication.

In order to insure rapid closure within the time limitation of working memory, each graphic must employ visual conventions that are accepted in a specific culture at a specific time. It must also assume a certain amount of background knowledge on the part of the viewer, or conversely, it must work to compensate the lack of background knowledge. Erring on the side of the latter, that is, providing extra knowledge regardless, is generally a common-sensical approach to design that shows editorial respect for the reader.

Design as it is currently taught relies chiefly on a visual framework that includes typography, layout and colour, in addition to gestalt psychology. This article suggests that the attention of instructors and designers also should be focused on the psychological principles that are at play in all graphics. While fundamentals, such as typography, layout and colour, are always the proper elements of good design pedagogy, they alone are not adequate to solve communicative problems that are never purely formal or purely visual, but depend on the limits of the viewer's working memory, relevant knowledge and values. Hence, every design problem is highly contextualized, specific, ad hoc and resistant to a formulaic approach.

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