Diagramming As A Strategy For Solving Graphic Design Problems

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Abstract

This paper examines the use of diagrams as a creative problem solving strategy. The focus is on the cognitive and perceptual operations supported on diagrams and how they might facilitate the process of creating representations with which to solve graphic design problems. It starts with an overview of how we solve problems in general and the role of representations in problem solving. It is followed by an outline of the ways in which diagrams amplify cognition in the context of a case study involving a class assignment. Ultimately, this paper suggests that diagramming can be an effective strategy for creating a representation with which to solve a complex graphic design problem. A representation that is "right" will foster new knowledge, insights and creations.

Key words

- diagrams
- problem solving
- information design

Introduction

Literature in cognition suggests that the key to problem solving is finding an efficient representation with which to solve a problem:

> **Solving a problem simply means representing it so as to make the solution transparent**. If the problem solving could actually be organized in these terms, the issue of representation would indeed become central. But even if it cannot –if this is too exaggerated a view–a deeper understanding of how representations are created and how they contribute to the solution of problems will become an essential component in the future of theory of design. (Simon, 1981, p. 153, my bold)

Simon refers to design in the realm of artificial intelligence. However, isn't that also true in the graphic design discipline? All graphic design activities, independent of their complexity and medium, involves some form of representation. How do graphic designers interpret and solve problems? What are the strategies used to find effective representations with which to solve problems? How do designers move from imprecision into clear, direct action?

This paper examines the use of diagrams as a creative problem solving strategy. It starts with an overview of how we solve problems in general and the role of representations in problem solving. It is followed by an outline of the ways in which diagrammatic representations amplify cognition in the context of a case study. The focus is on the cognitive and perceptual operations supported on diagrams and how they might facilitate the process of creating representations with which to solve graphic design problems.

Problem solving

The *Oxford Dictionary of Psychology* defines "problem solving" as a "cognitive processing directed at finding solutions to well-defined problems [...] by performing a sequence of operations."

Literature in cognition explains that when we solve problems we make use of both internal and external representations (e.g., Larkin & Simon, 1987; Norman, 1993). Although a fascinating topic, the forms that knowledge takes as internal representations (whether propositional, analog or procedural) will not be discussed here, since the focus is on external representations. It is often the case that mental activity is externalized in some form so as to minimize cognitive load and enhance cognitive abilities. External representations have a long history and can take different forms, such as notation systems, maps and other artifacts. As Norman (1993, p. 43) explains, external aids in the form of cognitive artifacts complement and strengthen our mental abilities:

> The power of unaided mind is highly overrated. Without external aids, memory, thought, and reasoning are all constrained. But human intelligence is highly flexible and adaptive, superb at inventing procedures and objects that overcome its own limits. The real powers come from devising external aids that enhance cognitive abilities.

Diagrams and problem solving

Diagrammatic representations have long and extensively been used in problem solving in different domains (e.g., from physics to music). There are well documented creative processes, such as those of Galileo, Einstein and Henri Poincaré, to mention three examples in the sciences (e.g., Miller, 2000; Wertheimer, 1945/1959).

Diagrams can be used in problem solving in two ways:

1. as a given representation (e.g., as the proposition to a problem): the data structure and the operations supported on it to solve the problem.
2. as a strategy (method) for redefining a problem, for creating a new representation (e.g., as a means to solve an ill-defined problem): the construction of an efficient representation with which to solve the problem.

Literature in Cognition and in Information Visualization (e.g., Bertin, 1967/1983; Card et al, 1999; Norman, 1993; Ware, 2000) suggests that the cognitive principles underlying graphic displays are:

- to record information;
- to convey meaning;
- to increase working memory;
- to facilitate search;
- to facilitate discovery;
- to support perceptual inference;
- to enhance detection and recognition;
- to provide models of actual and theoretical worlds;
- to provide manipulation of data.

Most research in the area investigates how diagrams and other graphic displays amplify cognition from the user's point of view: how diagrams are used as representations with which to solve problems, and to what extent the cognitive operations supported on them were efficient to the tasks at hand. The results provide invaluable guideline for effective diagram construction.

I would suggest that these cognitive operations are integral also to the process of creating a diagram with which to solve an ill-defined problem. A loop occurs as one creates a visual representation, interprets, makes adjustments and refines the representation until tailored to solving the problem at hand. The cognitive operations used in the process of creating a diagrammatic representation will be reviewed below in the context of a case study involving a classroom assignment.

Case study

The case study describes the creative process of undergraduate graphic design students in solving an information design problem. As in any information design class, the goal was to explore methods and procedures of structuring and visualizing information that would ultimately produce design solutions in which complex information is easy to understand and to use by a specific audience.

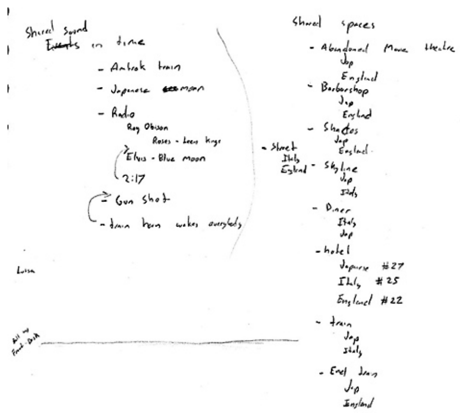

fig. 1

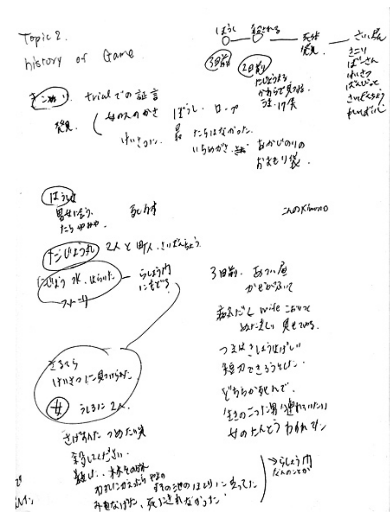

fig. 2

The topic of the assignment “Mapping Movies” is a cinematic narrative. Students were asked to select a film from a list of movies —specifically chosen for their non-linear features— and to solve the following problem:

goal:

to communicate the film structure to undergraduate film students in a way that facilitates search and perceptual inferences.

tasks:

- to organize the data in the cinematic narrative visually;
- to make explicit the patterns and structural relationships in the cinematic narrative;
- to create an informational diagram/map of the cinematic narrative.

The account that follows describes the students' process of creating a representation with which to solve the “Mapping Movies” problem. It is based on my empirical observations along three semesters and a total of 54 students. Two students were selected to illustrate the points discussed: Jonathan Rissmeyer with the movie *Mystery Train* by Jim Jarmusch; and Tomoko Yokoyama with the movie *Rashomon* by Akira Kurosawa.

The use of representations in problem solving

Movies are linear sequences of events happening in time and in space. Data is indexed by position in a sequence, adjacent to each other. It could be said that the “Mapping Movies” problem had a “poor” representation, in that it didn't support the operations for solving the problem at hand.

Students quickly understood that they had to create another representation with which to solve the problem. Most students used, in their first step, note-taking as a method to collect and gather data (fig. 1: by Rissmeyer; fig. 2: by Yokoyama). This involved watching the movie over and over again (as can be imagined, there were some complaints...). Most note-taking resulted in lists, which was not yet the best representation, since data was again indexed by position in a sequence. On the other hand, the notes were helpful in selecting and identifying the relevant components needed to proceed; and as a means of recording information, even though search was still hard.

In a seminal study, Larkin and Simon (1987) investigated the role of representations in problem solving involving computation. They compared the use of sentential to diagrammatic representations in the proposition of problems in Physics and Geometry. The fundamental difference between the two representations is how data is structured and indexed: the former linearly, by position in a sequence (elements are adjacent to each other); the latter spatially, by location in a plane (topological and geometric relations among elements).

Their results indicate that diagrammatic representations facilitated information-processing and were effective in:

- preserving explicitly the information needed for inference (usually implicit in the sentential form);
- facilitating search due to the spatial grouping of information needed to be used together for inference (as opposed to sentential, where search was linear and information not necessarily adjacent);
- supporting perceptual inferences which are easy for humans;
- facilitating recognition of relevant information, again due to perceptual cues.

Even though the diagrammatic representations were more effective than the sentential representations in the problems studied, Larkin and Simon warn that the use of a diagram doesn't insure efficiency in problem solving —that depends on how well the diagram takes advantage of the features listed above in relation to the task at hand. In other words, does the diagrammatic representation support efficient operations of search, recognition and inference? Furthermore, they suggest that the knowledge and ability to construct the most useful representation with which to solve a problem is itself central to problem solving.

Construction of diagrams

Once the students had gathered and recorded the data in the form of a list, the next step and challenge was to group information. Some students attempted at grouping and connecting elements in the list itself (e.g., using lines or color coding; see fig. 2: by Yokoyama). However, students realized that the list format didn't support an efficient way of searching, grouping and connecting information (confirming the results described above). Another kind of representation was necessary.

Movies are complex systems and dealing with complexity is not trivial. According to Simon (1981) complex systems are hierarchic (in a broader sense than simply representing relations of subordination), nearly decomposable and redundant structures. These properties allow the simplification of complexity, and ultimately, its representation.

All diagrams are abstractions of the data they represent, and involve the simplification and organization of selected information. Students were suggested to create diagrams as a strategy for the visual organization of data, in their case, now the items in the lists. I should say that some students discovered this strategy before the suggestion.

The construction of a diagram involves basically two interconnected processes:

- disintegration of the system to be represented: reducing it to essential components and relations, keeping relevant information and eliminating unnecessary details;
- integration of elements and relations in a spatial representation: visually organizing and structuring relationships.

Organization of information

Central to these two processes is the organization of data. Different classes of data require different types of organization (e.g., Bertin, 1967/1983; Card et al, 1999; Kosslyn, 1994; Ware, 2000):

- nominal: based on qualitative unordered sets, requires some other form of organization such as categorical, alphabetical, etc. (e.g., characters on a movie)
- ordinal: based on ordered sets, permits ranking of discrete data (e.g., the time when things happen on a movie)
- quantitative: based on numerical ranges, permits mathematical relations among data such as ratio and interval scales.

In the selected movies, besides time, which is an ordered scale and could eventually be used as a means to structure information, all other data was nominal and, therefore, required other ways of organization and classification.

Categorization plays a major role in grouping nominal information, which involves decisions on what components are grouped together and what kinds of relationships they hold. Categorization is also central to our ability to form and make use of knowledge schemata —models based on our experience of the world and on memory. We make use of knowledge schemata to structure what we

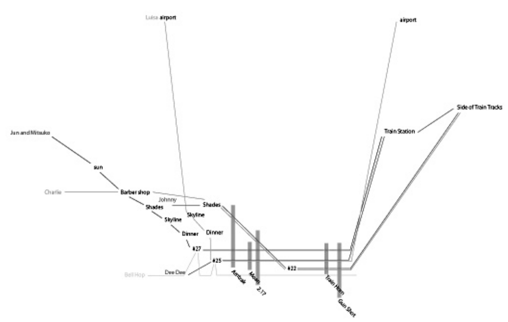

fig. 3

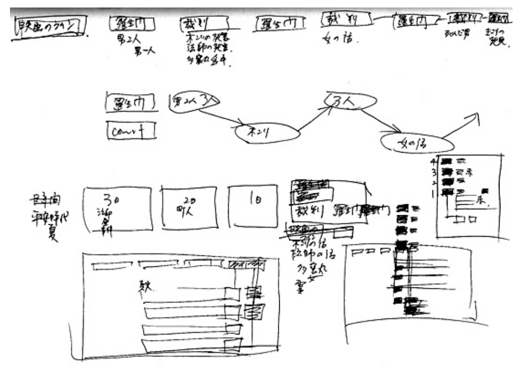

fig. 4

know and what we see (e.g., MacEachren, 1995; Pinker, 1990).

The creation of diagrams involves the translation of data organization into a visual form, which provides the overall visual structure, the visual schema. The visual schema can reflect knowledge schemata, the use of metaphors, or involve the creation of new models. Efficiency would be provided to the extent that the schema allows for correspondences between conceptual information and visual attributes (Pinker, 1990).

Literature in cognition suggests that a schema supports visual spatial reasoning, in other words, it can serve as an effective interface between perception and cognition. Above all, it facilitates the discovery of patterns and relations within the data (e.g., Card et al, 1999; MacEachren, 1995; Pinker, 1990; Ware, 2000).

The first attempts of organizing the data visually helped students in two fundamental ways. First, in the identification of problems with the data itself, which eventually resulted in collecting more data or simplifying the system even further. And secondly, in the discovery of patterns not foreseen or known beforehand, which resulted in new configurations of the overall visual schema. (fig. 3: by Rissmeyer; fig. 4: by Yokoyama)

Gestalt laws

It is through discrimination (same-different dichotomy) in early vision that elements and patterns are detected and ordered. Patterns are central to how visual information is structured and organized. As Ware (2000, p. 239) explains: “The brain is a powerful pattern-finding engine [...] If we can transform data into the appropriate visual representation, its structure may be revealed.”

The Gestalt psychologists developed a series of principles —known as the “Gestalt laws”— describing the way we detect patterns, how individual units are integrated into a coherent percept: proximity, similarity, common fate, good continuation, closure, simplicity, familiarity and the segregation between figure and ground (Wertheimer, 1923/1950). Understanding the Gestalt laws of perceptual organization is fundamental to the visualization of information. In fact, the laws can be used as design principles for effective ways of enhancing pattern detection and perceptual inferences.

For Wertheimer (1945/1959) the Gestalt principles are effective not only in enhancing perceptual inferences, but also in facilitating problem solving and thinking processes. He explains that the mechanisms of grouping, reorganizing, centering, etc., facilitate the understanding of the structural requirements of problems, allowing problems to be viewed as integrated and coherent wholes.

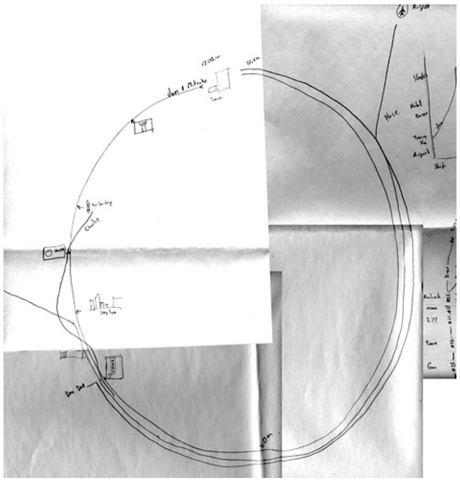

fig. 5

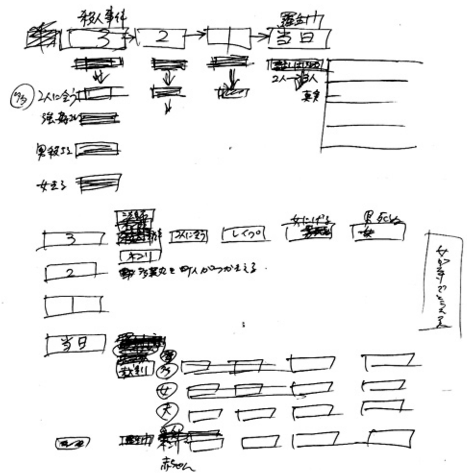

fig. 6

In diagrams, elements and relationships coexist in the same space and time and, thus, can be attended simultaneously. This factor together with the Gestalt principles of grouping helped students in the diagramming process. For example, students were able to detect elements that should have been spatially grouped together, but were eventually placed at distant locations, thus requiring relocation. Another way it helped them was in understanding the overall structure of the film and in the discovery of new relationships among elements.

Spatial organization

Literature in visual perception explains that spatial properties (position and size) and object properties (such as shape, color, texture, etc.) are processed separately by the brain (Kosslyn, 1994). And that position in space and time has a dominant role in perceptual organization (Card et al, 1999; MacEachren, 1995). Central to diagrams is the way data is indexed in space, in that efficiency in perceptual inference derives from how elements and relationships are graphically represented, which will, ultimately, facilitate search.

It is perhaps no coincidence that the ancient "art of memory" (Yates, 1966) relied on spatial information for augmenting long-term memory. Although used mainly as internal representations it is worth referring to its basic procedures. The rules varied throughout its history, but the most ancient and commonly practiced postulated the use of an ordered sequence of loci as placeholders for concepts, and of "active" visual images to stand for subject matters. It is quite fascinating how much these "invisible" mnemonic devices share with external diagrammatic representations: an artificial and ordered system made out of visual elements, properties and spatial relations.

Visual perception

Diagrammatic representations are dependent on visual perception for both their creation (encoding) and their use (decoding). All diagrams are spatial "mappings" of data and as such make use of graphical elements and properties to encode the data being represented. Meaning in diagrams is conveyed by means of symbolic references, where the graphic elements and the graphic structure in a diagram stand for elements and relations in another domain. Efficiency in conveying meaning and facilitating search will depend on how the visual description stands for the content being depicted, if the correspondences are well defined, reliable, readily recognizable, and easy to learn.

Understanding the constraints and capabilities of visual perception can enhance the way we organize and encode information in a diagram (e.g., pre-attentive features, visual acuity, etc.). Perception is an immense and complex field which, unfortunately, is beyond the scope of this paper.

fig. 7

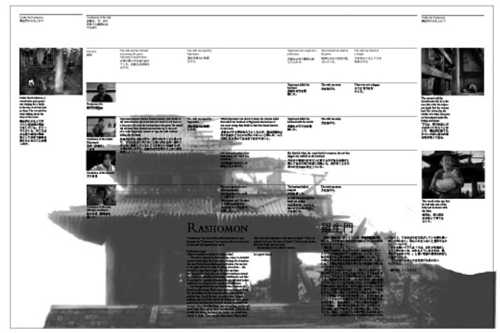

fig. 9

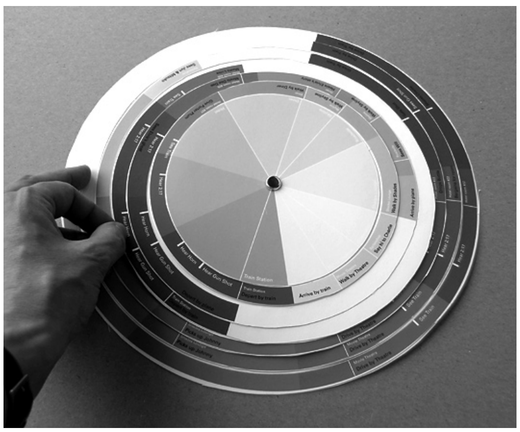

fig. 8

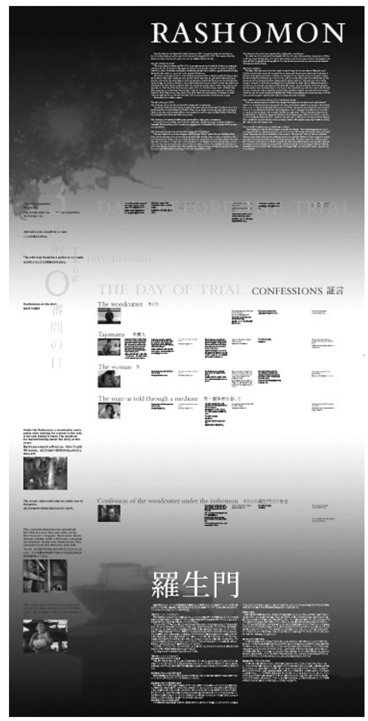

fig. 10

I would suggest that, during the process of creating a diagram with which to solve a problem, as described by the students' process, the graphic encoding of elements is less important than the visual organization of data and the overall structural relations. Search and discovery are enhanced if visual groupings and patterns are easily perceived, which will, ultimately, facilitate viewing the problem as an integrated whole. In this sense, the iterative construction of diagrams by the students happened in a very similar way to the use of an interactive information visualization, in that the process supported the manipulation and exploration of the data and facilitated new discoveries. (fig. 5: by Rissmeyer; fig. 6: by Yokoyama)

On the other hand, data coding played a crucial role while students were producing the final visual solutions. Data coding is central to the efficiency of diagrams in amplifying cognition from the user's point of view. Because of the constraints of this paper, the process of producing the final solutions will not be discussed here. Figures 7 to 10 show the first and last versions of the students' solutions, which might indicate the different steps involved (figs. 7-8: by Rissmeyer; figs. 9-10: by Yokoyama).

Conclusions

From my observations and from students comments, diagramming as a strategy for creating a representation with which to solve the "Mapping Movie" problem was helpful in:

- identifying problems with the data (e.g., need for collecting more data);
- understanding the problem as an integrated whole, by means of making the system (the elements and the relations) explicit (e.g., discovering overall visual structure);
- facilitating visual organization of data, by means of visual groupings and structural relations (e.g. relocation of elements that needed to be grouped together);
- facilitating pattern detection (e.g. identifying patterns not known beforehand)
- enhancing perceptual inferences, derived mainly from Gestalt principles and the use of visual schemata (e.g. discovering new relationships among elements);
- facilitating interpretation towards the use of a knowledge schemata or a metaphor with which to solve the problem (e.g., the representation of the problem as a circular schema suggested the creation of an informational wheel in Rissmeyer's final solution, see figs. 5 and 8).

The items listed above concur to empirical and scientific evidence suggesting that diagrams represent and communicate information in a way that is easy to perceive and to reason because they tend to exploit general perceptual and cognitive mechanisms effectively.

It could be said that creating a diagrammatic representation with which to solve the "Mapping Movie" problem was an effective strategy. It supported conceptual and visual spatial reasoning and, ultimately, it fostered insight and new creations, as can be seen in the final solutions (figs. 8 and 10).

It remains to be examined whether diagramming as a strategy could be effective in solving other graphic design problems. Its efficiency in solving problems such as interactive interfaces, and web sites, for example, is well known (Kahn & Lenk, 2001). It would be hard to imagine how to solve such complex problems otherwise. What about other less complex problems? Is diagramming an effective strategy for solving only complex problems? But even if only that is the case, it is necessary to acknowledge that designers nowadays face problems involving the organization and visualization of large amounts of data and complex systems. Would promoting the use of diagrams in design education help students solving complex problems later in their careers?

As with any other problem solving activity, the graphic designer's creative process involves, among other cognitive operations, searching for the appropriate methods and strategies with which to solve problems. Some methods are acquired throughout our studies and careers, and become part of our repertoire of learned skills, whereas others have to be created for specific problems. It is possible to suggest that, because of the nature of visual communication problems —which, independent of complexity, always involves visual organization and representation of information—, methods and strategies that make effective use of perceptual and cognitive mechanisms would be appropriate for solving graphic design problems.

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