The language of graphics
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In Chapter 2 we have examined the syntax of graphic representations. We have regarded a composite graphic object as consisting of a graphic space, a set of graphic objects that are contained in this graphic space, and a set of graphic relations in which these contained graphic objects are involved. In addition, we have already made several statements about the interpretation of graphic representations (section 2.1). Let us recall these:

The semantic analysis of the meaning of a graphic representation parallels the syntactic analysis of its structure.

The interpretation of a graphic object may be:

* an interpretation of it as an elementary graphic object, or
* an interpretation of it as a composite graphic object, constructed from:
  - the interpretations of the graphic objects that are part of it, and
  - the interpretations of the graphic relations in which these graphic objects are involved, which may partly be based on the interpretation of the graphic space in which they are arranged.

In this way the interpretation of a complex graphic representation (a composite graphic object) may be derived through several nested levels of interpreting constituting graphic objects, and interpreting the ways in which these are combined (their graphic relations).
There is a large amount of literature on the interpretation of graphic representations, mostly consisting of semiotically-tinted proposals to distinguish different types of graphic symbols. Taken together, the existing literature consists of a thick jungle of confusing and often contradictory terminology (see the ‘terminology comparison tables’ towards the end of both section 3.1 and section 3.2). In this chapter, in order to ‘sort things out’, we will develop a systematic and consistent approach to the main aspects of graphic interpretation, and apply this approach to numerous example figures. In addition we will, at the appropriate points in the text, use this approach to compare the existing literature on graphic interpretation, and to discuss specific shortcomings in that literature.

Let me give a brief overview here of the four sections of this chapter. In the first section (3.1), we will discuss type of correspondence. Type of correspondence is a core aspect of the interpretation of elementary graphic objects as well as of the interpretation of graphic relations between graphic objects. We will define type of correspondence as the relationship between what is shown and what is meant. The main types of correspondence that we will distinguish are literal, metaphoric, metonymic, rebus-based, and arbitrary-conventional. In the two remaining, shorter sections of this chapter we will briefly discuss two additional aspects that are involved in the interpretation of graphic objects: mode of expression and informational role. The mode of expression of graphic objects (section 3.2) concerns the classification of graphic objects into pictorial objects (in a spectrum from realistic to schematic pictures) and non-pictorial objects (abstract shapes, words and numbers). Sorting out a confusing issue in the literature, we will discuss the non-trivial relationship between type of correspondence and mode of expression. Concerning the informational roles of graphic objects (section 3.3) we will propose to classify graphic sub-objects of a composite graphic object either as information objects (which have to be adjusted if the information changes), or as reference objects (e.g. legends, labeled axes, grid lines), or as decoration objects. Finally we will make a few brief remarks about different types of represented information (section 3.4). First however, we will turn our attention to different types of correspondence that may be involved in graphic representations.
3.1 Type of Correspondence

"Signs are either literal or metaphorical. They are called literal when used to signify the things for which they were invented [...] They are metaphorical when the actual things which we signify by the particular words are used to signify something else [...]" (Book Two, p. 71).

[Letters, sounds and syllables have] "meaning not by nature but by agreement and convention [...] People did not agree to use them because they were already meaningful; rather they became meaningful because people agreed to use them." (Book Two, p. 101)

Saint Augustine (A.D. 397 / 1995)

In the quotes above, from more than 1600 years ago, Saint Augustine discusses the interpretation of signs, using three main terms that we will use in this section - 'literal', 'metaphorical', and 'convention'. However, while Saint Augustine uses these terms with regard to text, we will here propose corresponding notions that apply to graphics. In other words, we will focus specifically on notions of visual literalness, visual metaphor, and visual convention. Graphic representations differ from text in that they can 'depict' or 'show' things that we recognize.

In a graphic representation, we define type of correspondence as the type of relationship between what is shown and what is meant.

To give an example of a textual metaphor, one might say: "man is a wolf", where the use of the word 'wolf' would be regarded as involving a metaphor. In the context of this framework, such a (visual) metaphor would involve a picture of a wolf. Here we will not regard the written word 'wolf' as a (visual) metaphor, because we will be looking at the relationship between what is shown and what is meant. See the definitions of the various possible types of correspondences that are given below. What a written word or text shows, consists merely of strings of letters from the Latin alphabet. Consequently, in this framework such textual graphic objects will always be regarded as involving arbitrary-conventional correspondence (to interpret them, we need to be familiar with more or less arbitrary conventions).

The notion of 'what is shown' in a graphic representation is not a trivial matter. Goodman (1976) has taken the extreme point of view that recognizing depictions is not based on such a thing as 'natural resemblance' between the depiction and the depicted, but always on arbitrary conventions. Rich-
ards has devoted a chapter to this issue (Richards 1984, fourth chapter). Taking up these issues is beyond the aims of this thesis. Here we will assume that, regardless of the involved phenomena, people are somehow able to have the experience of ‘recognizing’ things in representations, and we will regard these things as ‘what is shown’ in a representation.

<table>
<thead>
<tr>
<th></th>
<th>what is shown</th>
<th>what is meant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>the display</td>
<td>the information</td>
</tr>
<tr>
<td></td>
<td>the representation</td>
<td>the represented</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Saussure:</th>
<th>signifier</th>
<th>signified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eco:</td>
<td>expression</td>
<td>content</td>
</tr>
<tr>
<td>Peirce:</td>
<td>representamen</td>
<td>interpretant and object</td>
</tr>
<tr>
<td>MacEachren:</td>
<td>sign-vehicle</td>
<td>interpretant and referent</td>
</tr>
</tbody>
</table>

**FIGURE 3-01**: Terminology for talking about representation.

Type of correspondence is the territory of *semiotics* - the study of ‘representation’. See the table in figure 3-01 for an overview of terminology that has been used in the semiotic literature for talking about representation. Ferdinand de Saussure and Charles Sanders Peirce are usually regarded as the founding fathers of semiotics. While Saussure’s ‘dyadic’ approach involves two elements (signifier and signified), Peirce’s ‘triadic’ approach involves three elements (representamen, interpretant and object). The ‘interpretant’ is *not* the ‘interpreter’, as it is misunderstood by some authors (e.g. by Mullet and Sano, 1995, p. 171). What Peirce *does* seem to mean with the term ‘interpretant’ is the *mental concept* that is activated in the mind of somebody who encounters the concerned representamen. As an example of the three elements of Peirce’s ‘semiotic triangle’, a process of representation may involve relationships between the three-letter word “dog” (the representamen), the mental concept of a dog in somebody’s mind (the interpretant), and a real-world dog (the object).

In the context of this framework we will prefer the dyadic approach followed by Saussure above the triadic one followed by Peirce. As already noted above, we will make the distinction between *what is shown* (for example the three letters “dog”, or a drawing of a dog), and *what is meant* (for example, a specific real-world dog, or our mental concept of a dog, or the set of all dogs). *What is shown* in a graphic representation consists of elementary graphic objects and graphic relations, which we have analyzed in various
3.1 Type of correspondence

ways in Chapter 2. *What is meant* by a graphic representation is derived by a viewer from *what is shown*. Different aspects of this derivation are the subject of the current chapter.

Concerning the nature of the relationship between *what is shown* and *what is meant*, it seems that a limited set of general possibilities can be identified. We will refer to these as *types of correspondence*. Elementary graphic objects as well as visual attributes as well as spatial structures may involve *literal*, *metaphoric* or *arbitrary-conventional* correspondence. See the table in figure 3-02 for some examples. For *elementary graphic objects*, there are two additional possible types of correspondence which we will refer to as *metonymic* correspondence and *rebus-based* correspondence. See figure 3-03 for examples of the proposed types of correspondence as they appear in Egyptian hieroglyphs. Many more examples of the different types of correspondence are described in the figure captions throughout this thesis. The following subsections consist of separate discussions for each of the types of correspondence. For now we will limit ourselves to brief definitions:

- **literal**: what is shown is based on *similarity* to the physical object or physical structure that is meant, or on similarity to a prototypical example of the kind of physical object that is meant.
- **metaphoric**: based on a (supposed) *analogy* between what is shown and what is meant, this may concern either a shared functional characteristic or a structural analogy.
- **arbitrary-conventional**: what is shown seems to stand for what is meant by *pure convention*, although in many cases the current users of the concerned representation may simply not be aware of the fact that the representation originated involving one of the other types of correspondence.
- **rebus-based**: based on the fact that (part of) the spoken word for what is shown *sounds* like (part of) the spoken word for what is meant.
- **metonymic**: based on a mental association due to the fact that there is (or used to be) a relationship of *physical involvement* between what is shown and what is meant (e.g. what is shown ‘is a part of’ or ‘is a possible result of’ what is meant, or in some other way it ‘plays a role in’ what is meant).
Type of Correspondence

<table>
<thead>
<tr>
<th></th>
<th>literal</th>
<th>metaphoric</th>
<th>arbitrary-conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>elementary graphic object</td>
<td>‘wine glass’ icon standing for ‘wine glass’</td>
<td>‘wine glass’ icon standing for ‘fragile’</td>
<td>‘elephant’ icon standing for ‘Republican party’</td>
</tr>
<tr>
<td>visual attribute</td>
<td>yellow desert versus green forest on a map</td>
<td>relative sizes of bars in a bar chart</td>
<td>color coding of electrical wires</td>
</tr>
<tr>
<td>spatial structure</td>
<td>the arrangement on a map, the connections in a wiring diagram</td>
<td>the arrangement on an x/y chart, the connections in a family tree</td>
<td>the arrangement of red above green on a traffic light</td>
</tr>
</tbody>
</table>

**FIGURE 3-02:** Literal, metaphoric and arbitrary-conventional correspondence apply to elementary graphic objects as well as to graphic relations (concerning visual attributes and spatial structure). For elementary graphic objects there are two additional possible types of correspondence: rebus-based correspondence and metonymic correspondence.

See the figures throughout this thesis for many more examples. Each example figure has a figure caption that includes an assessment of the involved type(s) of correspondence.

Type of correspondence should not be confused with certain other aspects of pictorial objects: All pictorial objects, regardless of the type of correspondence that they are involved in,

- may vary in their degree of pictorial abstraction, involving a spectrum from very realistic to very schematic (see section 3.2),
- may show an archaic example of the concerned object, i.e. an object ‘like it used to look’. For example, the postal horn displayed in figure 3-07 is an archaic object.
Type of correspondence in Egyptian hieroglyphs

- **literal:** bull

- **metonymic:** wind

- **metaphoric:** foresee

- **arbitrary-conventional:** 1000

- **rebus-based:** "w"

**FIGURE 3-03:** The five types of correspondence distinguished in this thesis can also be identified in Egyptian hieroglyphs. **SOURCE:** Composed by the author, individual hieroglyphs reproduced from Betrò 1995.
In this thesis, whenever we talk about the type of correspondence of an elementary graphic object, we will mean the type of correspondence of the shape of the elementary graphic object. In other words, regarding type of correspondence, an elementary object is equated with its shape (see also section 2.4 on visual attributes). After all, it is usually the shape of an elementary object that determines 'what we see in it'. Meanwhile, the elementary object's other visual attributes, such as size and color, and the object's anchoring(s) in spatial structure(s) may involve other types of correspondence than the type of correspondence that is involved in its shape. In this way an elementary object may be simultaneously involved in different types of correspondence. For example, a pictorial object may simultaneously involve a literal shape, an arbitrary-conventional color-coding, a metaphoric size in relation to the sizes of other objects, and a metaphoric spatial positioning along a time line.

In an analysis that our framework is definitely related to, Richards (1984) uses the term 'mode of correspondence', distinguishing 'literal' and 'non-literal' correspondence. Richards also includes the possibility of 'semi-literal' correspondence, partly because he does not allow an object to simultaneously be involved in different types of correspondence. He does not distinguish between the type of correspondence involved in an object itself (regarding its shape) and the type(s) of correspondence involved in its anchoring(s) in syntactic structure(s), or the type(s) of correspondence involved in its other visual attributes.

In addition to its intended referent (the concept that it stands for), a metaphoric, metonymic or rebus-based graphic object involves an intermediary referent (its literal interpretation). This applies to some arbitrary-conventional objects as well, for example to the elephant as a symbol of the Republican Party. In this sense, such objects involve a literal correspondence that serves as a basis for their metaphorical, metonymic or rebus-based or arbitrary-conventional correspondence.

In some cases the intended meaning of a graphic object involves several intermediary referents, where each step between referents has its own type of correspondence. For example, an interface button in a word processing program depicts a pair of scissors (first intermediary referent), the pair of scissors stands metonymically for the act of physically cutting into a paper document (second intermediary referent), and the act of physically cutting into a paper document in turn stands metaphorically for the act of removing selected text from the electronic document (intended referent). This phenomenon can be referred to as multi-step semiosis.

In the following subsections we will discuss the types of correspondence distinguished here, starting with literal correspondence.
3.1.1 Literal correspondence

Correspondence is literal what is shown is based on similarity to the physical object or physical structure that is meant, or on similarity to a prototypical example of the kind of physical object that is meant.

A literal elementary object depicts the kind of physical object that it stands for. Literal visual attributes express physical (spatial and visual) attributes of the represented objects. Literal graphic relations may represent a physical arrangement, physical links, physical separation or physical containment. In the context of this thesis the term ‘physical’ may refer both to physical things in the real world and to physical things that exist only in the imagination (e.g. a planned building, a fantasy creature). Possible synonyms for the term ‘literal’ correspondence include ‘physical’ correspondence and ‘direct’ correspondence.

![Figure 3-04](image)

FIGURE 3-04: A pictogram used in the catalogue of a company that rents party glasses. This pictogram involves literal correspondence: what is shown is a prototypical example of what is meant.

PHYSICAL STRUCTURES AND CONCEPTUAL STRUCTURES

Since our definition of literal correspondence uses the notion of a ‘physical structure’, let me make a few remarks about physical versus conceptual structures. Any ‘structure’ that is not a physical structure can be referred to as a conceptual structure. Likewise, any ‘space’ that is not a physical space can be referred to as a conceptual space.

Concerning their ‘literalness’, spatial structures that are displayed in graphic representations can be divided into three groups:

- Spatial structures that represent physical structures, involving literal correspondence. These are found for example in:
  - maps and pictorial diagrams (representing physical spaces), or in
  - wiring diagrams (representing physical links).
• Spatial structures that represent **conceptual** structures, involving *metaphoric* correspondence. These are found for example in:
  - statistical charts and time charts (representing conceptual spaces), or in
  - family trees and organization charts (representing conceptual links).
• Spatial structures that represent **hybrid** structures, involving both *literal* and *metaphoric* correspondence. See for example the graphic timetable in figure 2-29, and the 'U.S. population landscapes' on the front cover and in figure 2-30.

Note that some representations of physical spaces (e.g. subway maps) are *distorted* (subsection 2.5.2) and can be regarded as involving *distorted* literal correspondence. We will now turn to the discussion of *metaphoric* correspondence.
3.1.1 Literal correspondence

**FIGURE 3-05**: The pathways of glucose in the human body.  
**COMMENT**: The *containments* of certain substances in organs such as in the liver in the lower half of the figure, represent *physical* containments, involving literal correspondence. In contrast, the circles of Venn diagrams (e.g. figure 2-18) represent *conceptual* containments, involving metaphorical correspondence.

**SYNTAX OF SPATIAL STRUCTURE** (2.5): A composite graphic object that involves nodes, labels, linking by connectors, and containment by containers.

**TYPE OF CORRESPONDENCE** (3.1): *SPATIAL STRUCTURE*: The containment in organs involves literal correspondence, see the comment above. The linking by arrows involves metaphorical correspondence. **VISUAL ATTRIBUTES**: Some shapes (e.g. the kidney, muscle, brain, liver) involve literal correspondence, the remaining shapes involve arbitrary-conventional correspondence.

**TYPE OF GRAPHIC REPRESENTATION** (4): A link diagram that involves pictures.
3.1.2 Metaphoric correspondence

Correspondence is **metaphoric** if it is based on a (supposed) *analogy* between what is shown and what is meant. This may concern a structural analogy, a comparable function, or a shared characteristic.

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**FIGURE 3-06:** Two examples of graphic objects that involve *metaphoric* correspondence. In both cases, what is shown (wine glass, snail) ‘shares a characteristic’ with what is meant:

**Left:** A pictogram on a cardboard box, indicating a fragile content.

**Right:** ‘Go slow.’ This is one of the earliest pictographic suggestions for a traffic sign, from 1923. If this sign was interpreted as involving *literal* correspondence, it could be understood as a warning that there are snails ahead, crossing the street. **SOURCE:** Krampen 1965, p. 12.

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We have noted earlier that metaphoric correspondence may be involved in *graphic objects* as well as in *graphic relations* between graphic objects. Examples of metaphoric *graphic objects* can be found on many computer screens, such as the pictogram of a trash can, and the pictogram of a house standing for ‘My Homepage’ in an Internet browser. Some examples of metaphoric *graphic relations* are the arrangement of objects along a timeline (where distances stand for time intervals), the proportional sizes of bars in a bar chart (where heights stand for quantities), the linking of names in a family tree (where links stand for descent), and the containment in Venn diagram circles (where containment stands for set membership). In musical notation, both the horizontal and the vertical arrangement of the marks on the score involve spatial relations that are metaphoric: the ‘higher’ the mark, the ‘higher’ the pitch, and the further on the score, the further in time.
3.1.3 Metonymic correspondence

Correspondence is metonymic if it is based on a mental association due to the fact that there is (or used to be) a relationship of physical involvement between what is shown and what is meant. For example, what is shown ‘is a part of’ or ‘is a possible result of’ what is meant, or in some other way it ‘plays a role in’ what is meant.

Note that with the definition of metonymy that I am giving above, I am including what traditional rhetoricians refer to as ‘synecdoche’, where a part stands for the whole. I regard a synecdoche as a special case of metonymy. There are other authors who do the same (e.g. Lakoff and Johnson, 1980, p. 36). According to many scholars, both metaphor and metonymy play crucial roles in human cognition.

“Metonymy is one of the basic characteristics of cognition. It is extremely common for people to take one well-understood or easy-to-perceive aspect of something and use it to stand either for the thing as a whole or for some other aspect or part of it.”

Lakoff (1987, p. 77)

For examples of metonymic graphic objects see the various pictograms in figure 3-07. The Cross as a symbol of Christianity is another example that could be regarded as a metonymic graphic object. Tversky discusses pictorial metonymy and mentions that in the pictorial language of the Dakota Indians, ‘famine’ was conveyed by portraying empty racks for drying buffalo meat (Tversky 1995, p. 34, referring to Mallery 1893/1972).

Let me add a few remarks about the difference between metaphoric symbols and metonymic symbols. Both metaphor and metonymy in graphic representations can be regarded as ‘figures of depiction’ (a term from Tversky, 1995, corresponding to ‘figures of speech’), and they may sometimes seem confusingly related. However, the distinction between the two is quite clear.

• In the case of a metaphoric symbol, what is meant is compared to something that is neither part of it nor otherwise physically involved in it, and an analogy between the two is suggested.
• In the case of a metonymic symbol, no comparison is involved and no analogy is suggested. Instead, what is shown is either part of what is meant or otherwise physically involved in it.
FIGURE 3-07: Eight examples of graphic objects that involve *metonymic* correspondence. What is shown 'plays a role in' what is meant (or used to play a role), except for the skull at the lower right, in which case what is shown 'is a possible result'. The first four pictograms are from signage indicating a bar, a restaurant, bathrooms, and a hairdresser. The third row shows two different pictograms indicating a post office. The last row shows pictograms for a mine and for danger.
3.1.4 Rebus-based correspondence

Correspondence is **rebus-based** if it is based on the fact that (part of) the spoken word for what is shown *sounds* like (part of) the spoken word for what is meant.

Goldwasser refers to a rebus as a ‘phonetic metaphor’. She argues that, while “metaphor is built on the discovery of similarities, or on the creation and revelation of such between two *signifieds*, a rebus “is based not on any similarity of *signifieds*, but on similarity between *signifiers*”, the signifiers being spoken words in this case (Goldwasser 1995, pp. 71-72).

*Rebus-based* graphic objects have been involved in the early stages of the development of many writing systems. Figures 3-08 and 3-09 show rebus-based Egyptian hieroglyphs. In the course of their development, most writing systems came to be regarded as *arbitrary-conventional*. Arbitrary-conventional correspondence is discussed in the next subsection.

![Rebus-based Egyptian hieroglyphs](image)

**FIGURE 3-08:** Rebus-based Egyptian hieroglyphs.

COMMENT: When they were fully developed as a writing system, about two thirds of the Egyptian hieroglyphs had a rebus-based, phonetic function.

SYNTAX OF SPATIAL STRUCTURE (2.5): A horizontal separation, achieved by vertical separators, containing a segmented vertical lineup of graphic objects. The upper part of the second column shows objects that are contained by an elliptical container (indicating a Royal name).

TYPE OF CORRESPONDENCE (3.1): VISUAL ATTRIBUTES: The shapes of the majority of the displayed hieroglyphs involve rebus-based correspondence.

TYPE OF GRAPHIC REPRESENTATION (4): A written text.
3.1.5 Arbitrary-conventional correspondence

Correspondence is **arbitrary-conventional** if what is shown seems to stand for what is meant by *pure convention*. Concerning many representations that are regarded as arbitrary-conventional, the current users may simply not be aware of the fact that the representation originated involving one of the other types of correspondence.

Many arbitrary-conventional graphic objects actually do have a motivated origin, involving a *metaphor*, a *metonymy* or a *rebus*. However, when such an origin is forgotten, the graphic object will be perceived as being *arbitrary-conventional*. Thus an arbitrary-conventional representation is one that, while the original choice for it seems arbitrary, receives meaning through consistent use.

Examples of arbitrary-conventional *graphic objects* are written words, the elephant as the symbol for the Republican Party in the United States, and the Swastika as the symbol of the Nazi regime. Examples of arbitrary-conventional *visual attributes* can be found in many color-coding systems (e.g. of electrical wires, of subway lines). Arbitrary-conventional correspondence may involve either

- **external** convention, which is an established convention *outside* the representation at hand, or
- **internal** convention, which is not an established convention but an encoding that is consistent and carries meaning *within* the representation at hand, and is usually explained by some kind of *legend*.

![Figure 3-10](image-url)

**FIGURE 3-10**: The direction of writing is an arbitrary convention.

**SOURCE**: W. Eisner 1996, p. 49.
COMMENT: Written words involve two steps of arbitrary-conventional correspondence: one from meaning to sound, and one from sound to letters.

SYNTAX OF SPATIAL STRUCTURE (2.5): An integral metric space with graphic objects, three of which (the human figures) are labeled with containers (the word balloons) containing further graphic objects (three times the word 'sky').

TYPE OF CORRESPONDENCE (3.1): SPATIAL STRUCTURE: The integral metric space involves literal correspondence (spatial relations in the picture stand for spatial relations in an imagined physical world). VISUAL ATTRIBUTES: Like the integral metric space, the shapes that stand for physical objects involve literal correspondence (what is shown is what is meant). The word balloons on the other hand (both the shapes of the containers and the shapes of the contained word) involve arbitrary-conventional correspondence.

TYPE OF GRAPHIC REPRESENTATION (4): A picture.

The standard traffic light arrangement of positioning the red light above the green light is an example of a spatial structure that is arbitrary-conventional. This type of spatial structure should not be confused with spatial structures that are simply arbitrary but not conventional, such as a random scattering of graphic objects on a page. While an arbitrary spatial structure encodes no information, an arbitrary-conventional spatial structure encodes information through (arbitrary) convention. Relying on the information that is provided by the arbitrary-conventional arrangement of the traffic lights, color-blind drivers stop for the ‘top light’ and go with the ‘bottom light’.
Spatial arrangement may be partly arbitrary-conventional. We can make a distinction between two aspects of spatial arrangement:

- relative spatial arrangement (internal to the representation), e.g. spatial distances and relative directions within the representation, and
- directionality (how the representation is oriented), e.g. the cartographic convention of orienting maps with North at the top.

Often the relative spatial arrangement of objects in a graphic representation involves literal or metaphoric correspondence, while the involved directionality may involve culturally determined, arbitrary-conventional correspondence (see also Tversky 1995, 2001). See figure 3-10 (on reading from right to left), figure 3-12 ('orient'-ation of a map) and figure 3-13 (a 'counterclockwise' clock).
**FIGURE 3-13**: The clock face could also have developed to look like this.

*Source*: Norman 1990.

*Comment*: The direction of advancement of the clock is an arbitrary convention.

**Syntax of Spatial Structure** (2.5): A *metric space* involving a circular *metric axis*, two *point locators* (the two arms), and a *labeled circular grid line* (a circle of tick marks with numerals).

**Type of Correspondence** (3.1): *Spatial Structure*: The proportional distances along the circular time axis involve *metaphoric* correspondence, while the direction of advancement ('clockwise' or 'counterclockwise') involves *arbitrary-conventional* correspondence. *Visual Attributes*: The lengths of the two arms involve *arbitrary-conventional* correspondence.

**Type of Graphic Representation** (4): *A time chart.*
3.1.6 A look at the literature concerning type of correspondence

Various authors have discussed issues related to type of correspondence, see the table in figure 3.14 for an overview of commonly mentioned concepts.

Metaphor and metonymy in graphic representations can be referred to as ‘figures of depiction’, a term from Tversky (1995, p. 32) that corresponds to the ‘figures of speech’ or ‘tropes’ in spoken language. Horton (1994) uses the somewhat less elegant term ‘figures of image’.

<table>
<thead>
<tr>
<th>Type of Correspondence</th>
<th>literal</th>
<th>using a ‘figure of depiction’</th>
<th>arbitrary-conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowlton 1966</td>
<td>iconic</td>
<td>analogical</td>
<td>arbitrary</td>
</tr>
<tr>
<td>Arnheim 1969</td>
<td>picture</td>
<td>symbol</td>
<td>sign</td>
</tr>
<tr>
<td>Many authors</td>
<td>icon</td>
<td>-</td>
<td>symbol</td>
</tr>
<tr>
<td>Rogers 1989</td>
<td>resemblance</td>
<td>symbolic</td>
<td>exemplar</td>
</tr>
<tr>
<td>Barthes 1965</td>
<td>iconic</td>
<td>motivated</td>
<td>arbitrary</td>
</tr>
<tr>
<td>Horton 1994</td>
<td>subject directly</td>
<td>analogy, ‘figure of image’</td>
<td>conventions</td>
</tr>
<tr>
<td>Tversky 1995</td>
<td>straightforward</td>
<td>‘figure of depiction’</td>
<td>arbitrary</td>
</tr>
<tr>
<td>Peirce 1897</td>
<td>icon</td>
<td>index*</td>
<td>symbol</td>
</tr>
<tr>
<td>Richards 1984</td>
<td>literal</td>
<td>non-liter al</td>
<td></td>
</tr>
</tbody>
</table>

* At least a subset of the signs that Peirce calls “indices” seems to be related to the concept of metonymy. See the discussion in the text.

FIGURE 3-14: Comparison of notions in the literature that are related to type of correspondence.
On the following pages, we will discuss several of the distinctions from the literature as summarized in the table in figure 3-14.

According to Peirce, a sign may be an ‘icon’, an ‘index’, or a ‘symbol’. In the following I will briefly explore these three much-quoted categories. For each category I will reproduce relevant quotes from Peirce and then match his category to the concepts proposed here.

‘Icon’
Peirce’s notion of an a ‘icon’ concerns what other authors may call ‘isomorphism’:
• [An icon] “exhibits a similarity or analogy to the subject of discourse” (Peirce 1885 vol. 5, p. 243).
• “Icons comprehend all pictures, imitations, diagrams, and examples.” (Peirce 1886 vol. 5, p. 380).
• Peirce subdivides iconic signs into three categories: “Those which partake of simple qualities [...] are images; those which represent the relations [...] of the parts of one thing by analogous relations in their own parts, are diagrams; those which represent the representative character of a representamen by representing a parallelism in something else, are metaphors.” (Peirce 1902/1998, p. 157.)

Translated into our terminology, Peirce’s ‘icons’ include:
• literal graphic objects (Peirce’s ‘images’),
• metaphoric graphic objects (Peirce’s ‘metaphors’), and
• graphic objects that involve metaphoric graphic relations (Peirce’s ‘diagrams’).

‘Index’
• “Indices are signs which stand for their objects in consequence of a real relation to them. [...] Of this sort are all natural signs and physical symptoms.” (Peirce 1886, vol. 5, p. 379).
• One of the examples that Peirce gives for an ‘index’ is “a piece of mould with a bullet-hole in it as sign of a shot” (Peirce 1895/1998, p. 170).
• “The index is physically connected with its object” (Peirce 1895/1998, p. 168).
• “Psychologically, the action of indices depends upon association by contiguity” (Peirce 1895/1998, p. 172).

Although it is not clear whether Peirce’s notion of an ‘index’ would at all be applicable to intentional graphic representation, it does seem to have aspects in common with our definition of metonymic, which I recall here: “Correspondence is metonymic if it is based on a mental association due to the fact that there is (or used to be) a relationship of physical involvement between what is shown and what is meant. For example, what is shown ‘is a part of’ or ‘is a possible result of’ what is meant, or in some other way it ‘plays a role in’ what is meant (see subsection 3.1.3).
\textbf{Symbol}'
In some of his early work Peirce refers to a ‘token’ what he later calls a ‘symbol’.

- “The token represents its object in consequence of a mental association, and depends upon a habit. Such signs are abstract and general, because habits are general rules to which the organism has become subjected. They are, for the most part, conventional and arbitrary.” (Peirce 1886, vol. 5, p. 379.)

Peirce’s ‘symbol’ corresponds to our arbitrary-conventional graphic object.

Many other authors have adopted the term ‘symbol’ for arbitrary-conventional representations, contrasting it with the term ‘icon’ for literal representations, which is a narrower use of the term ‘icon’ than in Peirce’s writings.

\textbf{Arnheim} (1969, pp. 135-142) distinguishes three possible functions of images: an image may function as a ‘picture’, as a ‘symbol’, or as a ‘sign’.

As examples of ‘pictures’, Arnheim mentions a photograph, a painting of a Dutch landscape from the seventeenth century, and a simply drawn cartoon or caricature. Other examples he gives of pictures are a triangle as a picture of a mountain, and a drawing of two overlapping circles as a ground-plan for a two-ring circus. Arnheim’s ‘pictures’ seem to correspond to our literal representations.

As examples of ‘symbols’, Arnheim mentions how musical notation “represents the pitch level of sounds by the structurally analogous location of the notes on the staff”. Other examples he gives of symbols are arrows, a triangle as a symbol of hierarchy, and a drawing of two overlapping circles “that may be meant to show the logical relation of any two overlapping concepts”. Arnheim’s ‘symbols’ seem to correspond to our metaphoric representations.

Note that Arnheim’s use of the term ‘symbol’ is very different from Peirce’s use of the same term.

As examples of ‘signs’, Arnheim mentions letters and words in verbal languages, and a triangle as a sign for danger. Arnheim’s ‘signs’ seem to correspond to our arbitrary-conventional representations.

\textbf{Rogers} (1989, p.110) proposes a classification of icons, illustrated in figure 3-15. She distinguishes ‘resemblance’ icons, ‘exemplar’ icons, ‘symbolic’ icons, and ‘arbitrary’ icons. ‘Resemblance’ icons seem to correspond to our literal icons. It is not immediately clear what Rogers means with ‘exemplar’ icons. From her definition “An exemplar icon serves as a typical example for a general class of objects.”, one might expect her to mean our literal graphic objects, which often show a prototypical example of what is meant (see subsection 3.1.1). However, from the example that Rogers gives of an ‘exemplar’ icon - the knife and fork used on a sign that indicates a restaurant - and from her explanation that this sign “shows the most salient attributes associated with what one does in a restaurant, i.e. eating", I conclude her 'exem-
plar' icons correspond to what we refer to as metonymic graphic objects. Her 'symbolic' icons seem to correspond to our metaphoric graphic objects, and her 'arbitrary' icons to our arbitrary-conventional graphic objects.

![Figure 3-15: Classification of icons proposed by Rogers (1989): a) 'resemblance icons', b) 'exemplar icons', c) 'symbolic icons', and d) 'arbitrary icons'.](image)

In our terminology these involve: a) literal, b) metonymic, c) metaphoric, and d) arbitrary-conventional correspondence (this sign stands for 'biohazard').

**Source:** Rogers 1989, p 110.

**Richards** (1984, 2002) distinguishes between 'literal' and 'non-literal' correspondence. He also includes the possibility of 'semi-literal', partly because he does not distinguish between the type of correspondence of a graphic object itself (regarding its shape) and the type(s) of correspondence involved in the graphic object's graphic relations. See section 5.2 for a discussion of Richards' distinctions.

Recall that a graphic object may be simultaneously involved in different types of correspondence. For example, a pictorial object may simultaneously involve a literal shape, an arbitrary-conventional color-coding, a metaphoric size in relation to the sizes of other objects, and a metaphoric spatial positioning along a time line. None of the frameworks that can be found in the literature mentions or examines such a simultaneous involvement of different types of correspondence.

In this section we have discussed type of correspondence, which is concerned with the type of relationship between what is shown and what is meant. Type of correspondence is a core aspect of the interpretation of graphic representations, and is involved in the interpretation of elementary graphic objects as well as in the interpretation of graphic relations between graphic objects. We have identified a basic set of possibilities for type of correspondence, and we have discussed these possibilities, examining various examples. In the remaining sections of this chapter we will provide a brief discussion of modes of expression (section 3.2), the informational role that graphic objects may play within a representation (section 3.3), and the types of information that may be represented graphically (section 3.4).
3.2 Mode of Expression

Concerning its mode of expression, an elementary graphic object may be:

- a pictorial object: in a spectrum from a realistic picture to a schematic picture, or
- a non-pictorial object: an abstract shape, a word or a number.

Mode of expression is an aspect of graphic objects that is related to their type of correspondence. In section 3.1 we have pointed out that in addition to its intended referent (the concept that it stands for), a metaphoric, metonymic or rebus-based graphic object involves an intermediary referent (its literal interpretation). This applies to some arbitrary-conventional objects as well, for example to the elephant as a symbol of the Republican Party. In the latter case, the elephant is the intermediary, literal referent, while the Republican Party is the intended, arbitrary-conventional referent. In this sense there is a relation between type of correspondence and mode of expression: An elementary graphic object is regarded as a pictorial graphic object (a picture) if it involves a literal correspondence - either to its intended or to its intermediary referent. In other words, a pictorial graphic object functions as a depiction of a physical object or scene, which may be either its intended or its intermediary referent. A pictorial object can be situated on a continuum from realistic rendering to schematic rendering.

![Figure 3-16: An example of the spectrum from realistic picture to schematic picture. SOURCE: Scott McCloud 1993, p. 45.](image)

An elementary graphic object is regarded as a non-pictorial object if it involves no literal correspondence - neither to its intended referent nor to its intermediary referent. In other words, a non-pictorial object does not function as a depiction of a physical object or scene. It may be an abstract shape, a word or a number.

It follows from the above that a graphic object (e.g. a circle) may be pictorial in one context (e.g. as the head of a human figure), and non-pictorial in another context (e.g. in a Venn diagram).
WRITTEN TEXT

In the discussion above, we have listed words as a category of non-pictorial graphic objects. Words are the constituent objects of written texts like this one. In this framework, written text is regarded as a special case of graphic representation. Recall that we have defined a graphic representation as a visible artifact on a more or less flat surface, that was created in order to express information.

Written text is the special case of graphic representation in which:
- the syntactic structure of the representation is a lineup (long texts in Western languages are often vertical lineups of horizontal lineups),
- the graphic objects represent expressions in an existing human language, and
- the linear ordering within the lineup is determined by the sentential grammar of that language.

This definition of written text includes text in which the graphic objects are words that are composed with letters from the Latin alphabet, such as the written text you are reading right now. However, this definition of written text also includes text in which the graphic objects are pictorial symbols, such as Egyptian hieroglyphs and (ancient) Chinese characters. The lineup of graphic objects in written texts is often a segmented lineup, which was described in subsection 2.5.1 as a lineup that is broken up into several parallel shorter lineups, usually all running in the same direction (e.g. this line of text continues here).

**Written text is a special case of graphic representation.**

**FIGURE 3-17:** A sentence. SOURCE: Engelhardt 2002.
**COMMENT:** This figure serves to illustrate our view of written text as a special case of graphic representation.

**SYNTAX OF SPATIAL STRUCTURE (2.5):** A horizontal lineup of graphic objects.

**TYPE OF CORRESPONDENCE (3.1):** SPATIAL STRUCTURE: The linear order of the words involves arbitrary-conventional correspondence, following the grammatical conventions of the English language. VISUAL ATTRIBUTES: The shapes of the letters involve arbitrary-conventional correspondence, with the choice of letter combinations involving the more or less phonetic conventions of English spelling.

**TYPE OF GRAPHIC REPRESENTATION (4):** A written text.
Textual graphic objects, such as textual labels, are contained in many graphic representations. Different authors take different approaches to text within graphics. Richards for example explicitly chooses to omit textual labels from his analysis of graphic representations (Richards 1984, pp. 9/9). Horn on the other hand emphasizes the special and crucial role that words play in graphic representations (Horn 1998, pp. 57-58), and maintains that “tight integration of verbal and visual elements is the unique identifying feature of visual language” (ibid, p. 101). This notion of ‘visual language’ seems to imply that all graphic representations that do not contain textual objects (e.g. figures 2-08, 2-17, 2-20, 2-44, 3-06, 3-07) have to be regarded as not involving visual language. Concerning the treatment of textual objects, I agree with neither Richards nor Horn. In the syntactic analysis proposed in Chapter 2 of this thesis, textual objects are treated like all other graphic objects.
A LOOK AT THE LITERATURE CONCERNING MODE OF EXPRESSION

<table>
<thead>
<tr>
<th>Mode of Expression</th>
<th>pictorial</th>
<th>non-pictorial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arnheim 1969</td>
<td>realistic</td>
<td>non-mimetic</td>
</tr>
<tr>
<td>Bowman 1968</td>
<td>objective</td>
<td>conventional</td>
</tr>
<tr>
<td>Richards 1984</td>
<td>figurative</td>
<td>non-figurative</td>
</tr>
<tr>
<td>Bertin 2001</td>
<td>figurative image</td>
<td>non-fig. image</td>
</tr>
<tr>
<td>Horn 1998</td>
<td>image</td>
<td>word</td>
</tr>
<tr>
<td>Twyman 1979</td>
<td>pictorial</td>
<td>schematic</td>
</tr>
<tr>
<td>Krampen 1965</td>
<td>pictograph</td>
<td>diagram</td>
</tr>
<tr>
<td>MacEachren 1995</td>
<td>mimetic</td>
<td>arbitrary</td>
</tr>
<tr>
<td>Various authors</td>
<td>iconic</td>
<td>symbolic</td>
</tr>
<tr>
<td>Tufte 1983</td>
<td>picture</td>
<td>word, number</td>
</tr>
</tbody>
</table>

**FIGURE 3-18**: A comparison of terminology used in the literature to describe mode of expression.

Let us take a brief look at several of the distinctions that are summarized in the table in figure 3-18.

**Bowman** (1968 pp. 30-33) distinguishes ‘objective’ figures (*realistic pictures*), ‘associative’ figures (*schematic pictures*), and ‘conventional’ figures (*abstract shapes*). He offers a fourth category - ‘abstract’ figures - which, he says, represent information “in terms of pure visual logic”. From the examples that Bowman shows, we can conclude that his ‘abstract’ figures are graphic representations that express conceptual structures (see section 3.1.1) through the graphic relations between several graphic objects.
Richards' 'mode of depiction' is concerned with the degree of schematization that is involved in the depiction of an object (Richards 1984, p. 7/6). Mode of depiction may be 'figurative, semi-figurative or non-figurative'. A figurative element is high in pictorial detail, a semi-figurative element is schematized to a certain degree, and a non-figurative element is highly schematized (Richards 2002, p. 93). Without the aid of captions, context or conventions, we are unlikely to recognize what is represented by a non-figurative element (Richards 1984, p. 10/8).

Horn (1998) uses the appealing simple terms 'image', 'shape' and 'word', see figure 3-19.

Twyman (1979) offers a "schema for the study of graphic language" in the form of a matrix. He refers to our mode of expression as 'modes of symbolization', distinguishing four possibilities: pictorial, schematic, verbal/numerical, and combinations of pictorial and verbal/numerical.

Tufte distinguishes words, numbers, and pictures, where 'pictures' includes abstract shapes (Tufte 1983, pp. 10, 180).
MacEachren (1995, pp. 257-269) discusses ‘iconicity’ as a continuum from ‘mimetic’ to ‘arbitrary’ signs (see figure 3-20). This continuum corresponds to our continuum of pictorial schematization from realistic pictures to schematic pictures, extended at the schematic end to include our non-pictorial, abstract shapes. However, MacEachren notices the shortcomings of such a one-dimensional approach to ‘iconicity’ and struggles with problems such as “Where does metaphorical or metonymic correspondence fit in?” (MacEachren 1995, p. 262), and the related question of how to compare the ‘iconicity’ of a schematically rendered ‘direct sign’ with a realistically rendered ‘indirect sign’ (MacEachren 1995, p. 263), where ‘direct’ versus ‘indirect’ seems to refer to our literal versus our non-literal. These issues can be sorted out and clarified by distinguishing between what we are calling the mode of expression of a graphic object on one hand, and what we are calling the type of correspondence that the graphic object is involved in, on the other hand. We will now examine the relationship between these two.
RELATIONSHIP BETWEEN MODE OF EXPRESSION AND TYPE OF CORRESPONDENCE

In the previous subsection, we have discussed type of correspondence. We will now examine the relationship between a graphic object’s mode of expression and its type of correspondence.

![Diagram](image)

**FIGURE 3-21**: According to Richards, type of correspondence on one hand and mode of expression on the other hand are two independent phenomena (referred to by Richards as ‘mode of correspondence’ and ‘mode of depiction’). I believe that the category in the upper left corner (literal and non-figurative) is contradictory. See below for a discussion of this issue.


According to Richards (1984) mode of expression and type of correspondence are two independent phenomena (see figure 3-21). Assessing the literalness of a pictorial graphic object (‘figurative’ in Richards’ terminology, e.g. a little drawing of a machine), he judges the object by itself, disregarding the arrangement of several of these objects with regard to each other. This is indeed what we would expect for the assessment of the literalness of objects. However, when trying to assess the literalness of a non-pictorial object (‘non-figurative’ in Richards’ terminology, e.g. a single station marker in the London Underground diagram), Richards runs into a problem: There is no resemblance to any obvious primary physical referent. Without making this explicit, Richards then basically disregards the object itself. Instead, he looks at the literalness of the arrangement of several of these objects with regard to each other, in order to come up with a ‘literalness-judgment’ for that object. This aspect of Richards’ approach seems to be inconsistent.

As opposed to Richards, I would claim that the concept of graphic objects that are literal and at the same time non-pictorial (Richards: ‘literal and non-figurative’), is contradictory: As soon as a graphic object (e.g. a circle or a triangle) is interpreted as involving literal correspondence - in other words if
it is interpreted as depicting a physical object (e.g. the circle as depicting the moon, or the triangle as depicting a mountain peak) - it is pictorial. See the table in figure 3-22 for an overview of the relationship between mode of expression and type of correspondence.

<table>
<thead>
<tr>
<th>Mode of Expression:</th>
<th>Type of Correspondence:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>literal</td>
</tr>
<tr>
<td>pictorial</td>
<td>literal pictures</td>
</tr>
<tr>
<td></td>
<td>(what is shown is what is meant)</td>
</tr>
<tr>
<td></td>
<td>- Richards: literal and figurative</td>
</tr>
<tr>
<td></td>
<td>- Robinson et al.: pictorial</td>
</tr>
<tr>
<td></td>
<td>- Strothotte: presentational</td>
</tr>
<tr>
<td></td>
<td>- Commonly used term: iconic</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>non-pictorial</td>
<td>(a contradictory category)</td>
</tr>
<tr>
<td></td>
<td>- Richards: literal and non-figurative</td>
</tr>
</tbody>
</table>

**FIGURE 3-22**: Relationship between a graphic object’s type of correspondence and its mode of expression. For examples, see figure 3-23.
### FIGURE 3-23: Robinson et al.’s three categories of symbols correspond to three of the four quadrants in our table on the previous page - figure 3-22: ‘pictorial’ to our upper left quadrant, ‘associative’ to our upper right quadrant, and ‘geometric’ to our lower right quadrant.

**Source:** MacEachren 1995, p. 258, derived from Robinson et al. 1984.

<table>
<thead>
<tr>
<th>pictorial</th>
<th>associative</th>
<th>geometric</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="wildlife refuge" /></td>
<td><img src="image" alt="church" /></td>
<td><img src="image" alt="information center" /></td>
</tr>
<tr>
<td><img src="image" alt="bike trail" /></td>
<td><img src="image" alt="mine" /></td>
<td><img src="image" alt="historical marker" /></td>
</tr>
</tbody>
</table>

### 'ICONIC VERSUS SYMBOLIC' DISTINCTION IGNORES NON-LITERAL PICTORIAL GRAPHIC OBJECTS

While Richards proclaims type of correspondence and mode of expression as *two independent dimensions*, other approaches do exactly the opposite by treating the two as *one single dimension*, often using the terms ‘iconic’ and ‘symbolic’ for the two poles of such a dimension.

A commonly made distinction divides visual signs into ‘iconic’ signs and ‘symbolic’ signs. This distinction probably originates from Peirce’s ‘icon-index-symbol’ trichotomy, although it does not follow Peirce’s original broad concept of ‘iconic’. Peirce used the term ‘iconic’ in the sense of ‘isomorphic’, which includes structural analogy (see subsection 3.1.6). Many authors use the term ‘iconic’ in the narrower sense of ‘showing the visual appearance of what is represented’. In our terminology such ‘iconic’ signs are *pictorial, literal* graphic objects. On the other hand, signs that are commonly referred to as ‘symbolic’ are usually defined in the sense of ‘abstract and based on convention’. In our terminology such ‘symbolic’ signs are *non-pictorial, arbitrary-conventional* graphic objects. An application of this dichotomy is the classification by Strothotte and Strothotte (1997) into “presenta-
tional” pictures and “abstract-graphical” pictures. According to Strothotte and Strothotte, “presentational” pictures are “dominated by iconic signs”, where an “iconic sign” is “a sign that resembles what it stands for” (Strothotte and Strothotte, 1997 p. 51). “Abstract-graphical” pictures on the other hand are “dominated by symbolic signs”, where “symbolic signs” are “geometric primitives, arrows, lines, or text labels”, or mappings of “invisible properties onto visible attributes” (Strothotte and Strothotte 1997, p. 46).

This simple dichotomy between ‘iconic’ and ‘symbolic’ would work well if pictorial signs would always stand for what they depict, and if arbitrary-conventional signs would always be non-pictorial. The fact is however, that many pictorial signs do not stand for what they depict. In addition, arbitrary-conventional signs may be non-pictorial as well as pictorial. As we have seen, many pictorial graphic objects are based on metaphor, metonymy, or arbitrary convention. Think for example of a pictogram of a wine glass standing for ‘fragile object’ (metaphor), of the pictograms of human figures on signs for bathrooms (metonymy), or of the elephant standing for the Republican Party (arbitrary convention). All these symbols fall outside the ‘iconic’ versus ‘symbolic’ distinction. They are not ‘iconic’ because they do not stand for the object that they show, and they are not ‘symbolic’ because they are pictorial.

Finally let me note that a non-pictorial symbol (which is always non-literal, see the table in figure in 3-22) usually involves arbitrary-conventional correspondence. Sometimes however, metaphoric connotations of an abstract shape may play a role, such as a round shape standing for harmony (described by both Arnheim and Horton). Some color-coding systems could possibly be regarded as involving both metaphoric and a metonymic correspondence. For example, one might argue that red as a color for warning and danger involves a metaphoric correspondence between a dangerous object or situation on one hand, and glowing fire or blood on the other hand. Representing these objects (glowing fire or blood) by their red color could be regarded as involving metonymic correspondence.
3.3 Informational Roles of Graphic Objects

In Chapter 2 we noted that, regarding the structure of a graphic representation, the graphic sub-objects of a composite graphic object can play different syntactic roles. In this section we will look at the fact that, regarding the interpretation of a graphic representation, the graphic sub-objects of a composite graphic object can play different informational roles. Concerning such informational roles of graphic objects, we propose to divide graphic objects into information objects, reference objects (e.g. legends, labeled axes, grid lines), and decoration objects.

Information objects are the graphic objects that would have to be adjusted if the information (data) that one intends to represent would change. Examples of information objects are the bars in a bar chart or the shaded areas on a weather map that show the regions where it is expected to rain the next day.

Reference objects are the graphic objects that a) serve to enable the interpretation of information objects, and that b) would not necessarily have to be adjusted if the represented information (data) would change. Reference objects clarify the specific language or representation ‘schema’ (section 1.1) of the representation that they are part of. We can divide reference objects into spatial reference objects and legend objects:

- The function of spatial reference objects is to mark a meaningful space. Examples: Axes and their annotations, grid lines, familiar landmark features on thematic maps (e.g. towns and coastlines on a rainfall map). In the graphic multiple in figure 2-45, showing Los Angeles air pollution, the labeled map at the top is a spatial reference object.

- The function of legend objects is to explain symbols and/or visual attributes that are used in a graphic representation. Most legend objects are composite graphic objects, structured as a table with one column displaying (some of) the used symbols and/or visual attributes, and another column displaying a verbal or numerical explanation of their meaning. Example: The boxed composite graphic object in the lower right corner of the subway map in figure 2-32 is a legend object.

Decoration objects are graphic objects that serve neither as information objects nor as reference objects, and that could be erased without affecting the intended representation of data (information). They serve as embellishment, and may or may not be related to the context and theme of the represented information. In some cases a graphic object that seems to be a decoration object at first glance, may actually be regarded as an information
object or a reference object, because it provides important contextual information.

As an illustration of informational roles note that in a standard classic clock face there are only two information objects: the two arms of the clock. The remaining objects such as tick marks (for hours and possibly minutes) and numerals are all reference objects.

The informational roles described above apply to graphic objects in their entirety. Separate visual attributes of graphic objects (e.g. shape, texture, color) can also be classified concerning their informational roles, as either informative or decorative visual attributes.

**A LOOK AT THE LITERATURE: EMPHASIS ON INFORMATION OBJECTS**

"A warning seems justifiable that the background of a chart should not be made any more prominent than actually necessary. Many charts have such heavy co-ordinate ruling and such relatively narrow lines for curves or other data that the real facts the chart is intended to portray do not stand out clearly from the background. No more co-ordinate lines should be used than are absolutely necessary to guide the eye of the reader and to permit an easy reading of the curves."

*Willard C. Brinton (1914, p. 346)*

"Since the grid is simply a frame of reference, it should be visually subordinated so that the trend curve can be clearly distinguished".

*Bowman (1968 p. 49)*

A ‘curve’ as mentioned in these quotes is an information object, while a ‘co-ordinate ruling’ or ‘grid’ is a reference object. Most authors advise to minimize spatial reference objects and decorative objects.

**Bertin: Subject matter versus reference elements**

Concerning the visible marks in a graphic, Bertin makes the distinction between what he calls *subject matter* and *reference elements* (Bertin 1983, pp.175, 180-181, 190). The *subject matter* consists of the elements “which constitute the information”, also referred to by Bertin as the “content” of the graphic or the “meaningful marks”. The *reference elements* or *reference components* on the other hand are the “background”, also referred to by Bertin as the “meaningless marks”. The subject matter is “figure” while the reference elements are “ground”.


Bertin notes the importance of separating the subject matter from the background. In this context Bertin talks about the “total amount of black” in a graphic, and about the “portion of black” that is devoted to reference elements rather than to subject matter. To increase legibility, Bertin calls for “a reduction in the visibility of the background” (the reference elements) and “an increase in the visibility of the subject matter” (Bertin 1983, p.181). See Bertin’s illustration that is reproduced here as figure 3-24. To demonstrate his point, Bertin first separates a graphic (first row of the figure) into reference objects and information objects (second row). He then reduces the amount of black (visibility) of the reference objects, and increases the amount of black (visibility) of the information objects (third row). He finally rejoins reference elements and subject matter (fourth row).

**Tufte’s ‘data-ink ratio’**

Tufte (1983, 1990) makes beautiful books in which he propagates the use of more ink for what we call information objects, and less ink for what we call reference objects and decoration objects, resulting in a high ‘data-ink ratio’. He basically says the same as Bertin, but uses other words.

Tufte divides the total ink used in a graphic into data-ink and non-data-ink. Data-ink is the portion of the graphic’s ink that displays the actual data. For example in a scatter plot, the axes and the grid are non-data-ink, while the dots marking the measurements are data-ink. The data-ink ratio is the ratio of data-ink to total ink. Tufte’s design principle of increasing the data-ink ratio basically means reducing the amount of non-data-ink. In the course of striving for high data-ink ratios, Tufte introduces several related concepts:

- **De-gridding** - making reference grids less prominent - is one way to increase the data-ink ratio.
- In more general terms, a way to increase the data-ink ratio is to emphasize the figure and to de-emphasize the ground.
- **Chartjunk** is Tufte’s term for the presence of a lot of non-data-ink, such as decoration objects and heavy grids. Chartjunk has a low data-ink ratio.
FIGURE 3-24: From top to bottom: A redesign as proposed by Bertin, reducing the visibility of the background (left side), and increasing the visibility of the subject matter (right side). SOURCE: Bertin 1967/1983, p. 181.
### Informational Roles

<table>
<thead>
<tr>
<th></th>
<th>Information object</th>
<th>Reference object</th>
<th>Decoration object</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bertin 1967</td>
<td>subject matter</td>
<td>background</td>
<td>-</td>
</tr>
<tr>
<td>Wilkinson 1999</td>
<td>-</td>
<td>guides</td>
<td>-</td>
</tr>
<tr>
<td>Tufte 1983</td>
<td>data-ink</td>
<td>non-data ink</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3-25:** A comparison of terminology that is used in the literature, and in this thesis, to describe different informational roles of graphic objects.
3.4 Type of Represented Information

The various graphic means that we have discussed in Chapter 2 tend to be used in certain typical ways. For example, different quantities of something are often expressed by different sizes (such as in a bar chart), while different categories of something are often expressed by different colors (often explained in a legend). Quantities and categories are different types of information. Types of information and the appropriate graphic means for representing them have been extensively examined and discussed in the existing literature. These aspects of graphic representation are not a focus of this thesis, so the few general remarks in this very brief section serve merely as pointers to these issues, included for the sake of completeness.

The most-cited author regarding types of information and their matching to appropriate graphic means is Jacques Bertin (1967/1983, 1977/1981, 2000/2001). Many authors who write about the use of visual attributes in graphic representations explicitly refer to Bertin's work as their basis (e.g. Richards 1984, p. 8/5; MacEachren 1995, p. 270; Card, Mackinlay and Shneiderman 1999, pp. 26-30; Wilkinson 1999, p. 118). The common main distinction that is made concerning types of information is into nominal, ordinal and quantitative information (quantitative information is also referred to as 'numerical', 'interval' or 'ratio'). A nominal attribute concerns categories, an ordinal attribute concerns a ranking, and a quantitative attribute concerns quantities. The table in figure 3-26 shows which visual attributes are generally considered appropriate for representing which types of information. For a brief discussion of visual attributes see section 2.4 of this thesis.

In the existing literature most attention concerning the matching of information to graphic means has concentrated on the use of attribute-based relations such as variations in size or color. Concerning the use of spatial relations, such as separation by a separator or arrangement along a metric axis, some considerations can be found in Tversky's work (1995, 2001). The table in figure 2-35 of this thesis gives an overview of which kinds of spatial structures express which types of information. For example, separation by a separator usually expresses nominal information, while arrangement along a metric axis expresses quantitative information.
Two additional kinds of distinctions that can be made regarding type of represented information are the distinction of concept-to-attribute relationships versus concept-to-concept relationships, and the distinction of physical structures versus conceptual structures:

- Nominal, ordinal and quantitative information involves concept-to-attribute relationships. Concept-to-concept relationships are relationships that can be expressed graphically through linking by connectors.
- The distinction between the representation of physical structures and the representation of conceptual structures is discussed in subsection 3.1.1.

This very brief summary concerning types of information that can be expressed in graphic representations brings us to the end of this chapter. In the next chapter we will discuss the classification of graphic representations.