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Some graphical paradoxes in the design of subway maps: The case of the Madrid Metro 2007–2018

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The subject of this article is a set of twenty different metro-maps of the city of Madrid, published between 2007 and 2018. They serve their purpose as navigation aids to public space in such a remarkable diversity of design that one could easily assume that they represent different cities. This phenomenon illustrates what Jacques Bertin calls the 'basic graphic problem', ie. that 'graphics offer an unlimited choice of constructions for any given information' (Bertin 1983: 100). Nevertheless, there are also significant similarities: all these maps show network-like structures with two types of objects: places (knots) and connections (edges). The main priority of all maps is the relation between stations and route sections. Therefore, it is remarkable that the real spatial relations are indicated differently on each map, from more realistic ways to highly abstract ones. In none of the maps can a naturalistic similarity be found. The act of transcribing the object 'city' into the medium 'map' must rather be seen as a new constitution. Every map is made within the scope of the graphic inventory - like arrows, lines, etc. - newly constituted under the premise of the relevant relations. At first glance, it can hardly be decided which map is most suitable for its intended purpose. Do these variations result from a contingency that is necessarily implicated in any act of design? Therefore, is there always a non-operationalizable residue in design that cannot be reduced to the semiotics of maps? The paradoxical relationship of contingency and translation in design can be identified in this material residue. A sign is not necessarily linked to the signified but always has a surplus meaning. On the other hand, what is the irreducible element that must be contained in all maps of the Madrid metro system as their non-contingent core? In light of the premise that there can be no correct or complete transcription of Madrid's metro system, our attention is focused on the relations between the object and its representation. Our hypothesis is that each map generates a different image of the city of Madrid. Every transcription has its pluses and minuses, entails benefits and losses. But the dissimilarity with the object must

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not be regarded as a defect. Rather, an epistemic surplus can be seen in every new construction as a way of graphic worldmaking.

KEYWORDS schematic maps, map semiotics, graphic design, cognitive design, abstraction, pragmatic design

Introduction

In his short story 'Del rigor en la ciencia' (engl: *On Rigour in Science*), Jorge Luis Borges quotes an imaginary work of 1658 written by the fictional author Suárez Miranda. He describes a nameless kingdom which was reproduced by a perfectionist cartographer on a scale of 1:1. So accurate was the representation in every single detail that the map corresponded perfectly with the empire. This map also marked the end of the science of cartography in the kingdom, for its over-ambitious, meticulous realism rendered the map itself useless in terms of its use as a means of spatial orientation (Borges 1982: 121). A map with such a high degree of similarity is elusive in terms of the excess of information it contains, makes it impossible to distinguish between the details essential for navigation and other random details which are less relevant for that purpose. Coping with the abundance of material is not accomplished by its repetition. Indeed, the most realistic, most detailed illustration of such an object is not necessarily the one that provides the best orientation. Every map must *simplify* the territory it aims to represent. This is achieved by means of an interpretative proficiency in the decoder manifesting itself in the recognition of relevant aspects. Cartographic design options range from accurate topographical reproductions on a unified scale to highly schematic maps. The latter do not attain their epistemic efficacy by adhering to the standard or by complying with the proportions of the components. On the contrary, their epistemic effect appears to stem from their very (relative) *dis*similarity.

In order to investigate the phenomenon discussed above, I have chosen as an example different maps of the Madrid metro. Metro maps are schematic plans that depict relations in public transport. They are a special type of map and apparently have very little topographical similarity with their denotation. If one overlays a classic map with a metro map of the same region, one would not be able to come to a perfect fit (see Figure 1). The usefulness of a metro map, specifically, lie in its relative dissimilarity to its object of representation. In terms of its user-friendliness, the schematic map is in no way inferior to the classic city map. In some ways it is even superior, although the latter is much more realistic. The difference is that a metro map primarily depicts the relations between stops and sections of lines. Real spatial proportions are more or less neglected in favor of the relations between the elements.

Figure 1. Overlay of a classic map with metro map of same region

In this article, I examine twenty examples of maps of the Madrid metro system published between May 2007 and April 2018 (see Figures 2-21 at the end of the text). I chose this period because in May 2007, a major expansion program of the Madrid metro was completed. Subsequent to this program, stops were added until 2011. *La Fortuna* station was added to Line 11 in October 2010, and the extension of Line 2 from *La Elipa* to *Las Rosas* was opened in March 2011. The new section of the line includes three stops (*La Almudena*, *Alsacia* and *Avenida de Guadalajara*) and ends at *Las Rosas* station. Since these recently completed sections are only extensions of former lines, they will not affect our investigation.

Some of these maps went into circulation simultaneously. This circumstance becomes relevant insofar as the maps are so strikingly different in their form that one could easily get the impression that they represented different cities while – and this is equally amazing – they all seem equally fit for their purpose: navigation. Neither map is more or less correct than the other with regard to their function – navigation in local public transport. Our aim is to examine this startling variety of representations of the same object – the Madrid Metro network (which did not change significantly in that period of time). Why do the plans, while representing the same object with the same relation of stops and lines, show such a high degree of variation? Where do these represntational dissimilarities come from? At first, it seems that the usability would be proportional to their degree of similarity to their object. It is easy to conceive even more designs depicting the Madrid metro that can guide their users to their destinations, as long as the maps are able to show the relations between the elements and reduce the excess of information to what is necessary.

In the first section I explain in general terms what metro maps are. Then I look at the wide range of possible designs. Can the dissimilarity to the depicted object be ascribed to a contingency necessarily inherent in every act of design? (Hoffmann 2008: 18) More than thirty years ago, Jacques Bertin formulated the graphic paradox of the variability of designs that have invariable levels of user-friendliness: 'graphics offer an unlimited choice of constructions for any given information' (Bertin 1983: 100).

In the second section I discuss this paradox which he calls 'the basic graphic problem (Bertin 1983: 100). Each of these versions of the Madrid metro map was constituted within the

framework of design conventions, such as recurring iconic inventories (arrows, lines, and other signs), and on the condition of obtaining the relevant relations. The designers of these plans used various graphic generalization techniques to extract important information and create an overview and clarity.

In the central third section, I ask an epistemologically fundamental question which also emerges concretely in the specific schematics of subway plans. The fundamental question is: are we still looking at representations? Are these maps still representations of already existing objects, or are they rather constructions of those objects? The construction of the metro map must accommodate what is irreducible, which necessarily has to be contained in each of the maps of the Madrid subway, if it is still going to be a metro map of Madrid.

So, does the contingency of the multiple variables associated with the construction have a non-contingent core? That is what we will seek to find out in the fourth section. How do the previously identified correlations between contingency and non-contingency, translation and construction interact in the design of the maps? Why it is necessary to step back from an object in order to better recognize it? Why must a dissimilar representation of the subject metro network be designed in order to unfold a practicability through this very deviation or 'detour', if this practicability refers to the objects denoted by the representation? Why this detour? And does it matter which graphical detour is taken? If dissimilarity in the form of abstraction is the decisive criterion that raises the metro map to the status of an epistemic tool, then how can one explain the circumstance that in theory there is an infinite number of possibilities which represent the subject 'public transport network'? The challenge is to clarify the relationship between contingency and non-contingency in map design according to the key question of the *irreducible*.

1. What are subway maps?

What is it that constitutes schematic maps like metro maps? The graphic task here is mainly to simplify the representation of the area without reducing the number of relations among the relevant components. Simplification means to use the basic principles of map design, such as abstraction, selection, transformation and generalization. To enable the reader to master the source material, graphic processes are used to extract individual data from the abundant material and make it comprehensible for us by means of internal coherence and standardization.

Metro maps function as signs with a network-like structure defined by two types of objects: places (nodes) and relations (edges). They serve the purpose of navigation in a public transport system and usually provide only a rudimentary orientation in the immediate vicinity of the metro station. The user of a metro map has, as a rule, one specific question in mind: 'How do I get from station A to station B?'. The plan shows users which line they need to take to reach B and where they have to change lines if necessary.

According to a functionalist concept of signs, the plans fulfil the function of an extensional reference. Every detail of the plan is figurative in the sense of referring to 'something out there'. The semiotician Bertin defines maps as 'geographically ordered networks' (Bertin 1983: 173). He proceeds to clarify that 'a graphic is a geographic "map" when the elements of a geographic component are arranged on a plane in manner of their observed geographic order on the surface of the earth' (Bertin 1983: 285). According to this definition, are metro maps still maps? In order to apply Bertin's definition to metro maps, one must first identify what can be considered a 'component' in a plan and how many components there are. In the case of metro maps, according to Bertin, the generic term 'component' can be used to subsume, for example 'all metro lines in a city', and their 'element' would accordingly be a single metro line. The length of the component is given by the number of metro lines listed in the plan. If we look at the metro plans, we see that the elements of a geographic component have obviously not been 'arranged on a plane in manner of their observed geographic order on the surface of the earth'. Rather, the components of these plans, and indeed both the geographical background components as well as the components of the transport network, have been abstracted according to different sets of rules. These rules determine angle, line weight, line shape, scale, colors, handling of intersecting lines, intersection of lines and points, handling of parallel lines, degree of distortion of topographical information, and other aspects, such as typography and additional icons. First of all, a metro plan uses both dimensions of the plane, and the more components there are to be displayed, the more complex is their design. The questions and problems faced by the designer are how to schematize the information of the territory. An overview of the designer's range of possibilities is offered by Dirk Burghardt, Cécile Duchene and William Mackaness (2014) in their publication 'Abstracting Geographical Information in a Data Rich World: Methodologies and Applications of map Generalisations'. They quote operations like collapse, smoothing, geometric stylization or caricature.

Let us investigate this regularity by considering the line course and its angles: metro maps usually record line courses as (straight) lines cleared of cartographic microcrenulations. The angles are usually unified. There are plans with 45 and 90 degree angles or with 30, 60 and 90 degree angles. There are also free forms with simplified courses, whose curves have undergone arbitrary simplifications and do not follow a fixed pattern, and plans in which the lines describe circles and arches. Parallel lines are separated for better readability, usually at a 0-distance.

According to Bertin, a metro plan should be seen as a 'cartogram', as a construction that distorts a geographic network so that non-topographic components can also be represented. Topographic accuracy is no longer paramount (Bertin 1983: 285). As with the Mercator or Peters projections, this results in a 'linear problem', i.e. the problem of 'equidistant projection'. According to Bertin, there is no satisfactory solution; trade-offs always have to be made (Bertin 1983: 290).

The scale often varies within a metro map. For practical reasons, in the downtown area, where many routes converge, it is comparatively large. The stops are relatively close together. The large scale is necessary to capture all the stops and display them so that they are legible.

In the periphery of a city, a smaller scale is sufficient to accommodate all relevant information. The construction of a schematic plan of this kind has the purpose of coherence and simplification, for example, by the approximation of angles, and it must be designed in such a way that even components can be detected which are needed for the understanding and not directly relate to the represented territory. Thus, if there is an inconclusive representation, some linguistic explanation providing the missing equivalences must be added. Although they do not relate to the territory directly, the names of the stops and other additional information, such as service points and transfer stations, must be included in the map. Diverse thematic icons must adequately be implemented, e.g. icons for the elements of the component 'different types of vehicles'. Such inserts are placed in the map and thus require their space, but cannot be understood as topographic elements. At these points, multiple components overlap in a map, a problem that has to be solved by design (Bertin 1983: 285).

In schematic maps one usually finds information about the geographic terrain in the background of the network only if it is necessary for the extended orientation in the area of the lines' network. The representations of the genuinely topographic elements of the components 'water bodies' have a visually supportive function for the orientation in the city or the area and are therefore often also shown only in relation to the metro line courses. The area in the map denoting, for example, the river Rio Manzanares, usually corresponds only marginally with the real topographical position of the river. The course of the river has been simplified to a higher or lower degree (see Figure 22). The operations of simplification do not always prevent the identification of the river by means of geographic matching, but the geographical identification has become secondary and any recognisability is less attributable to the specificity of the river. In the case of the river, the possibility of identification results from the written addition, from the river's designation as Rio Manzanares. Figure 22 presents examples of abstractions or free forms of line courses. A graphic designer can choose between the omission of smaller loops and their retention by exaggeration. Both choices are generalizations. The number of possible rules is potentially infinite.

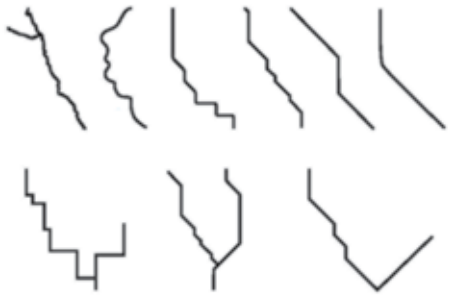


Figure 22. Higher/lower degree simplifications of the river Rio Manzanares

2. The graphic problem

This infinity of possibilities leads to the situation that every designer can come up with their own solution. There are a number of different maps for the use of the Madrid metro. In this great diversity of maps, there is a plurality of projection methods, if the design method, due to its topographical dissimilarity, can be described as a 'projection' at all. This cartographic term, referring to the transposition of geographical conditions by means of geometrically justified mapping rules, is only of limited suitability with regard to metro maps. Metro maps are not based on unified projection methods, such as the Mercator or the Peters projections for topographic maps. The task here is not to map a curved surface plane of the earth by rendering it two-dimensionally. 'Projection' in metro maps means, for example, to geometrically reconstruct the elements of the transport network onto a map and to design a network.

The methods of projection are always artificial, whether they are framed by an existing method or freely constructed, according to an individual set of rules. The graphic paradox which, according to Bertin, represents 'the basic graphic problem', can be recognized not only in the construction of the 'cartogram', but also in any design that can be classified as 'emblematic', certainly in the case of the metro map 'representation'. Bertin describes the freedom one possesses to transcribe any given component by one of the eight visual variables[1] or by a combination of several of these variables (Bertin 1983: 9).

For example, a graphic designer can translate a geographic component using a single dimension of the plane, by which he constructs a diagram, or using the two dimensions of the plane, by which he constructs a map. He can use variations of color or tone. 'In fact. to construct 100 different figures from the same information requires less imagination than patience. However, certain choices become compelling due to their greater "efficiency"' (Bertin 1983: 9). The graphic designer is faced with the question of what type of map to produce. Even if decided to design a 'cartogram', there is an infinite number of visual variants that correlate differently with the components of the information.

You can easily see this if you allign the different maps to the same scale and place them on top of each other (Bertin 1983: 100). They are all equally well-suited to help people find their way through the metro network. Although they appear to give conflicting information, they are all equally correct representations. The production of each representation implicates the suppression of another representation, suggesting a play of presence and absence. Thus, each metro map essentially reveals that there are several ways to design a metro map. The mere existence of such a map, because of its presence, and the evidence of the visibility of each possible variant of its design, is the very prerequisite for the semiotic function of its elements. As such, we can see that graphical transcription always means both information loss and information gain. The question is whether any twenty different maps of the same system are epistemically equivalent.

Let us approach this question from a pragmatic perspective: A map serves to make a city accessible. What significance does the variance of possible constructions have for this pragmatic purpose? What does it mean to make a city accessible using signs? If we suppose that the signs in a metro map, no matter how abstract, correspond to things in the world (if the map refers to an existing subway network), the process of this correspondence can be figured approximately like this: If the sign has a real referent (for example, a node in a map for an intersection of lines), what is the relation between all the signs and, thus, between all the represented components in the city? Readable information in the map is constructed from the real relations between the real world referents of its components and elements. The graphical representation transferred the real world referents to the relations between various visual variables that denote the various components and elements. Typical questions a user might ask include, 'Where do I have to get off ?', 'Where do I have to change trains?', 'What's there to find in that place?', or 'Is the stop near the river?'. These questions can be answered without a 'metric evaluation of distances' (Bertin 1983: 299). According to Bertin, they only require that it be possible to differentiate, classify or count the elements. 'It only matters that these useful elements be discernible and that the differences, the order, the numbers (within the limits of visually memorisable quantities) constitute a recognizable reference system' (Bertin 1983: 299).

Thus, one can easily locate oneself on a metro map given he can distinguish metro stops on the map from other 'information elements', if one knows which stop is at, or where line A crosses line B, so that one is able to deduce where to change. A metro line cannot be identified in the map by its real topographical location, but by its coding, in the sense of a graphic order and the possibility of differentiation. Equidistant projection and scale are not relevant factors for the correctness of the relation (Bertin 1983: 299). But the topography is not completely banished from the map. Locational relations, such as the configuration of river and metro line, still play a certain role, but their exact topographical location is never the sole purpose; it only figures as a kind of subsidiary information for manageability and orientation. Due to the distortion, the river cannot be displayed on maps according to its exact topographical position, but only in terms of what is located in its environment. By displaying the river or the surrounding vegetation, the user gets a clue that helps them locate their current location or final destination by aligning their position with the river in accordance with the map. The element 'river' serves as a reference. In order for the river, as a basic map element, not to compete visually with the metro line itself or other 'elements of more specific information' (Bertin 1983: 311), simple and clear signs are used which are kept slightly in the background of metro lines. The hierarchical order between river and metro lines is therefore usually represented by different grades of brightness (Bertin 1983: 311).

In terms of purpose and manageability, design decisions are made which are abstractions of the source material. Even with regard to the already mentioned 'set of rules' which can be found in metro maps, the designer still has endless possibilities from which to choose how to

construct the metro lines (including accessories). It is not possible to catalogue these possibilities. We are dealing with a continuum that can range from a minimum of topographical similarity to its maximum. The extent to which the whole spectrum from the minimum to the maximum can still be called 'iconic' – and not just those maps that can be located on the scale well within the range of maximum topographical similarity (and thus are very obviously commonly viewed as 'similar' to what is depicted), will be discussed further on. The 'optional variants' that Bertin addresses do not contradict their purpose of codification. But do the different ways of representation not have any influence on content and function? Breaking down the navigation in local public transport to simple questions (How do I get from A to B?), one can clearly determine whether navigation succeeds or not. Depending on the graphic rendition, it is only possible to decode – in positivist terms – what fits into the grid of the representation. In highly schematized representations, such as metro maps, a unified set of rules helps users to find an answer to the question (How do I get from A to B?) as accurately as possible. The design is sealed, as it were, against interpretation. Due to the simplicity, any arbitrary deviation from the design rules would be read as meaningful and pose an uncertainty factor: What does this or that curve mean, or this or that blot? So the question is whether the different variants, which could also be called formal methods, and to which the coding does not apply have an epistemic effect. The word 'method' implies an intention and thus the differences would be intended. They are shown, for example, (1) in the scale, (2) in the angles, (3) in the line curve, (4) in the line width, (5) in the colors of the lines, (6) in the way parallel lines are dealt with, (7) in the representation of overlaps (8) in the space between parallel lines, (9) in the way nodes are dealt with and (10) in the size and representation of stations, (11) in the degree of distortion/retention of the topography of the lines, (12) in the degree of distortion/retention of all other topographic information (13) in the way geographical reference information is treated, and (14) in the way typography and the additional map icons are used.

Bertin says that in any graphic transcription, the content must necessarily be separated from the form. 'Information is a series of correspondences observed within a finite set of variational concepts of "components". All the correspondences must relate to an invariable common ground, which I will term the 'invariant'" (Bertin 1983: 16). This assessment is clearly made in the tradition of the epistemological and linguistic approach of French structuralism. If I agree with Bertin's working hypothesis that the content (i.e. the information regarding all questions of navigation in the Madrid metro network) remains constant, what possibilities are there for the graphical system to impart this content? Which variants stem from the listed 'mapping methods' that could certainly be expanded? And are the maps, according to the premise of the separation of content and form, only different forms and therefore epistemically equivalent? How strongly is our thinking dependent on graphic practice? Where is the threshold above which the representation is too distant (too dissimilar) and below which the representation is too close, too similar?

3. The relationship between transcription and construction in cartograms – a paradox

To transcribe and transform graphically the bulk of information of a metro network into a smaller number of meaningful elements can be regarded as a case where form interferes with content. A distinction between content and form seems doubtful, however, because metro plans are made of graphically produced semiotic constructions. In this respect, I would disagree with Bertin. The design of the metro maps is based on a construction but nevertheless a representational function is obviously present, simply because, by using these maps, one can navigate from A to B. How does one deal with this contradiction? A schema is not an attempt to replicate 'things out there'. Its function is to help people get an idea of the 'things out there'. This must be understood as a graphic-cognitive achievement.

As I have suggested, maps give succinct answers to what Bertin refers to as the 'preferred questions' (Bertin 1983: 154). These questions are 'How do I get from station A to station B?', 'Where do I have to get off?', 'Where do I have to change trains?', 'What's there to find in this place?' or 'Is the station near the river?'. But one could think of many more questions. For example: 'How many miles is it from A to B?', 'Is it a beautiful place?', 'Who lives near the bus stop?', 'Is there a park bench?'. The answers to these other questions remain elusive. Thus, the map design decides which functions of the graphical representation are to be fulfilled (Bertin 1983: 154). Bertin states that 'the method encompasses all the processes which rely uniquely on the correspondences contained in the information being processed' (Bertin 1983: 170). But then what does 'similarity' with the denotata actually mean? It's a common sense notion that a portrait of a person is similar to the person depicted.

Following Eco, we should ask what it means exactly when a portrait has 'the same characteristics' as the person whom it represents (Eco 1972: 200). Eco replies: 'Because it has the same shape of the eyes, the nose, the mouth, the same complexion, the same hair color, the same stature …', only to immediately bring up some objections: 'But what does that mean, "the same shape of the nose?". The nose is three-dimensional, while the image of the nose is only two-dimensional'. Eco (1972: 201) adduces a number of other reasons why the portrait is not exactly similar to the person depicted. He concludes that, in the final analysis, such verification only leads to the destruction of the concept of the 'iconic sign'. And only the denotatum itself can be an iconic sign of itself (Eco 1972: 201).

Eco (1972: 201) disagrees with solving the dilemma by acknowledging that an iconic sign is similar to what it denotes, by suggesting that this is 'a definition that can satisfy common sense but not semiotics'. Eco replies from a semiotic perspective that iconic signs would reflect '*some of the conditions of the perception of an object*' after '*having been selected on the basis of recognition codes and specified, according to graphic conventions*' [emphasis in the original]. In other words, relevant features of a denotatum must be interpreted and communicated by

graphic signs. Thus Eco (1972: 206) concludes: 'So there is an iconic code that specifies the equivalence between a particular graphic sign and a relevant trait of the recognition code'. According to Eco, graphic characters can transcribe denotata. Therefore, there is 'a relationship of equivalence between the two'.

Hans-Jörg Rheinberger, the science historian, would not agree with this definition. He is situated at the other extreme of the debate spectrum, namely on the constructivist side. In his essay 'Dimensions of Representation in the Practice of Scientific Experimentation' he writes, with regard to the problem of representation in science, that no matter which (conventionalized) form of representation you choose, there is no interpretation or representation of *something* out there. Rheinberger's argument goes against the assumption that there was a 'presence of something which the presentation refers to' (Rheinberger 2000: 236). In the course of these and other constructivist positions of recent decades, the idea has become prevalent that maps are no longer considered representations of something, but rather processes that generate their own representations in the first place (Rheinberger 1997: 9). According to this post-representational view which sees maps as original rather than re-presented constructions, the condition of construction is at the center of the analysis. In *Experimental systems, objects of investigation, and modes of representation* Hans-Jörg Rheinberger examines the relation between representation and intervention (Rheinberger 1997: 9). He argues against a neat epistemological separation between the representation and the represented (which we have come to know from Bertin) and acknowledges representation to be a science-generating force (Rheinberger 1997: 9).

According to this view, maps can be seen as epistemically effective objects and thus understood as both *representation* and *represented* at the same time. From this perspective, one can ask if subway maps have an effect on facts – and, if so, what this effect is. Do maps merely depict their object of representation, the public transport network, or do they construct it? From the latter perspective, there would be as many different 'Madrids' as there are maps. Is it possible to go so far as to acknowledge maps as original constructions, i.e. novel recreations of the topographic source material? Is (a) another Madrid than (b)? (See Figure 23).

In her essay *Karten erzeugen doch Welten, oder? (Maps create worlds, don't they?)*, Sybille Krämer presents another opposite to the constructivist view. She diagnoses a 'discrediting of image and similarity', in the course of which the suitability of maps to depict a territory (or even its iconicity itself), is increasingly being questioned (Krämer 2012a: 153). Krämer argues that the pragmatic purpose of maps to the user (as an aid to navigation), cannot be achieved by refusing to recognize a similarity relation between map and territory. Thus, an imaginary localization of the map user on the map is a precondition for a 'cartographic operation', as Krämer (2012a: 153) puts it, and is inconceivable without the similarity relation between map and territory. Yet one might ask what paradoxical kind of similarity this is if, as already said, the applied nature of the map results from its abstraction. Is it similar to what you see or to what

you know? According to Krämer, the signs on a map are connected to the area by similarity. Let us go back to Eco for this once more. According to Eco (1972: 207), the iconic sign can be similar in three ways: (1) in terms of optics, (2) ontologically (i.e. in relation to an assumed similarity), and (3) as conventionalized similarity.

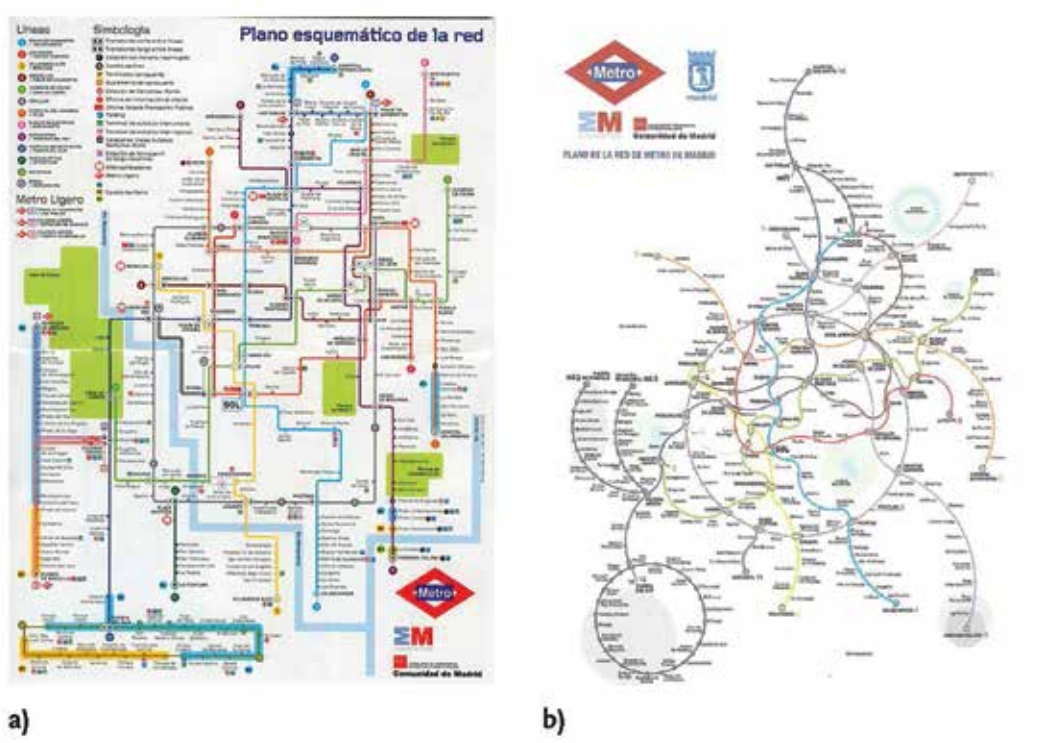


Figure 23. Examples of two different map designs of the subway network of Madrid

Should we not identify this last, which Eco identifies as the iconic sign, as a social construct? And is the schematized map, in the sense of a conventionalized similarity, recognizable as a product of actors which retroacts as an intermediary back into society? So doesn't the design of the metro map determine the behavior of the user, give her options for action and therefore have a constitutive effect?

If one regards graphic production as a cultural activity, one can actually identify the graphic elements on the maps as elements of a construction that represents the ideas of the city (such as the public transport networks) two-dimensionally as a synopsis of individual signs (Rheinberger 1997: 9). According to Rheinberger (1997: 9), what happens here is a 'production of symbols'. Representation is thus captured as a cultural, and, more precisely, graphic matter. The production process of representation is socially situated, as it is produced by human agency. If we follow Rheinberger's suggestions, we recognize that the inherent laws of graphic signs

and the immanent logic of design are in fact, in a certain way, constitutive of their objects. The symbolic character, with its own logic, seems anything but 'ontologically justified' and yet it is able to cause action (1997: 13–14). Thus, the design designates which designed object will be put to work, and it sets the course for further uses.

In this way, metro maps, which refer to existing cities, are social products. The varying (re)presentations of a subway network set the tone for an action, in this case for successful navigation of a local public transport system. I will give it a try: Each subway map has its own specific cognitive access which gives it a variation in its functional focus. Comparing the two maps 'Plano esquematico de la red' (a) and 'Red de Metro en el municipio de Madrid' (b) (see Figure 24), I can recognize that the readability in terms of 'where does one need to change from one metro line to another' is higher in map (a) than in map (b). Map (a) is more suitable for a particular purpose, the navigation in the metro system. On the other hand, map (b) can be aligned with one's mental image of Madrid in terms of its streets, places and landmarks. It delivers more general information about the territory, with the result that the user can place the metro system in a wider context of the region. Whereas with (a) this alignment is only possible in a very limited way.

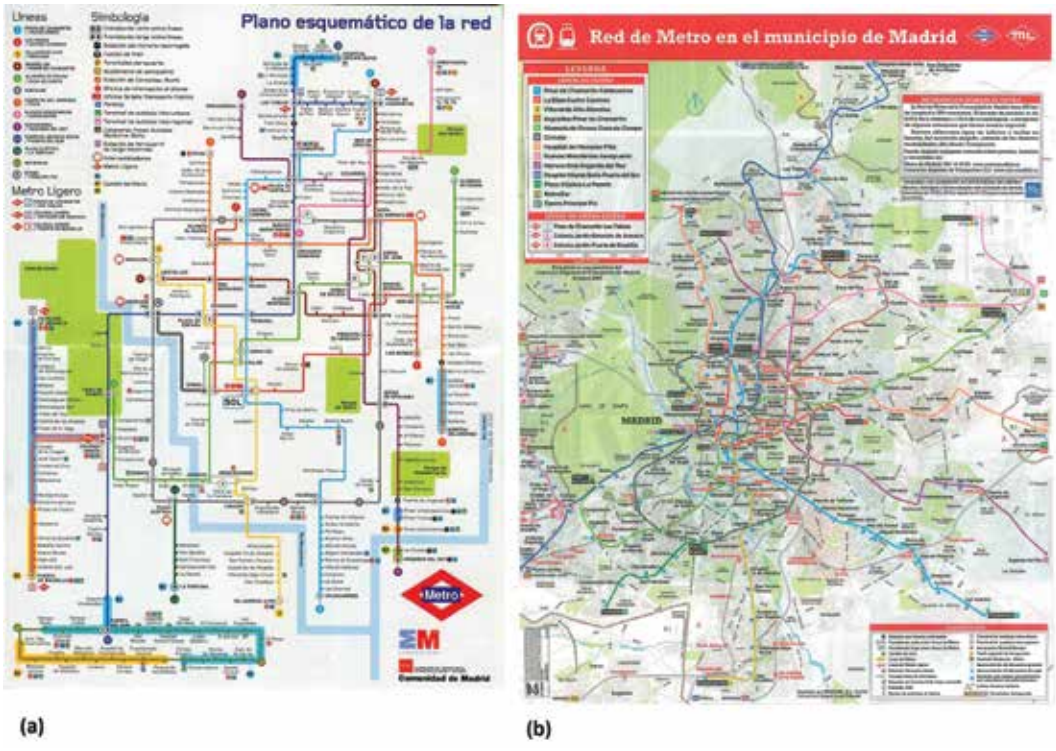


Figure 24. Functional focus variation in two map designs

Do the characters develop their own dynamics, ignoring their intended design and use? The thesis would be that the graphic elements of a map cannot be completely reduced to their meaning and that the semiotically unavailable and meaningless 'remnants' are also epistemically effective. Thus, iconic signs are not readable in their entirety, but they possess a 'visual appearance that is detached from its function of readability' (Mainberger 2011: 220).

Yet, I cannot detect a creation of something representative through representation, as Rheinberger suggests. At this point, a distinction must be made between the context in which knowledge is generated (the graphic design of a map) and the context of knowledge (the area which the map conveys a knowledge of). Both the map and the subway itself are social phenomena, and the fact that the map instructs action can easily be understood. But what would be the presumed constitutive power of the map with reference to the city? Or vice versa: how does the map refer to the city which is being re-constructed by it, and has this association with its denotatum, if there is any, something to do with similarity?

The problem seems to be solved if one does not understand similarity pictorially. According to Stefan Günzel, one can comprehend the map as a diagram whose similarity to its object is a diagrammatic similarity. Günzel follows Pierce in that he understands the diagram as a special form of the iconic sign. Thus, a diagram is not similar to its denotatum in the same way as a portrait is similar to a person. A diagram is relationally similar to what it represents (Günzel 2013:108). In the case of the metro map, this relational similarity is associated with (pictorial) dissimilarity.

A metro map can also be examined as a diagram. Its topographical dissimilarity, recognizable by its non-compliance with scale, size, and distance, the straightening of routes and the exclusion of details, goes along with a more or less clear display of the relevant relations between the elements. According to Günzel, these representations produce what they show. Again, he resorts to Peirce: Now it becomes clear why the iconic sign is 'single-digit', in contrast to the index, which is 'double-digit' because it refers to reality, and the symbol, which is 'three-digit' because it includes communication and reality. Icons are 'auto-icons' because they represent their own reality. Günzel describes cultural science's understanding of the diagrammatic representation as a 'show of ideas' in which it is irrelevant whether the denotata are materially present (Günzel 2013:110).

One could argue (and thereby contradict both Rheinberger and Günzel), that a metro map, understood as a diagram, unfolds its 'generating power' in the sense of a representation that itself produces its denotatum (here: the action), and can only ever do so in relation to a preexistent reality. Diagrammatic operations of this kind can think through future processes only by referring to something that already exists. The graphical synopsis of relations in the form of subway lines allows for future actions, precisely because it transforms a complex area (the city and its public transport network) into a sphere of action – the sphere of action of the diagram in the form of a network map, which is what a subway map is. This

makes practicable what is impracticable, and intangible entities can be worked with in concrete terms. According to Sybille Krämer, it can be said that these diagrams open 'operating rooms' (Krämer 2005: 23).

In agreement with Sybille Krämer, we can understand this two-dimensional kind of knowledge generation as operative images (Krämer 2012b: 82). As for maps, she speaks of a 'fundamental reciprocal relationship between generating and mapping'. The central question is how the diagrammatic epistemic process in the handling of metro maps works in detail as a pragmatic function (purposeful locomotion in the territory of the city). How are a city and its public transport network transferred to the similarity of the relation and thus made manageable, via the detour of the dissimilarity of the abstraction? The depiction of the relation and the construction of the design, the meaningful and the meaningless components, interact with each other (Krämer 2012a: 155).

In metro maps, navigation is only possible if there is a relational similarity between map and city, so that users of the map can position themselves in it and think through their routes, and this 'intended locomotion can be transferred into an intentional movement in the life-world space' (Krämer 2012a: 157). (A Hamburg subway map would be of little avail to them in London[2]). According to Krämer (2012a: 157), this self-placement on the metro map creates 'the link between the symbolic world of the map and the real life world of the map users'. This double navigation (imaginary on the map and real, or physical, in the subway) is possible through a 'match between territory and map', made possible by the similarity described above with Günzel as relational and by Krämer as 'structural similarity' (Krämer 2012a: 157).

As a tentative summary, it could be argued that this correlation cannot be generated on the premise of a strict distinction between content and form, representation and represented (Bertin 1983), nor on the premise of an identification of content and form, representation and represented (Rheinberger 1997, 2000). On the other hand, it cannot be assumed that, no matter what variation the designer makes from the infinite spectrum of possibilities, the information about the (re)presented area is substantially invariable. This shows that a new theoretical conception of schematic representation is needed. This should not rely on the (de-) constructivist view of Rheinberger nor on the representationalist notion which understands schematic maps solely in their representational function, as transmitters of knowledge about space. In our final section the question posed is: What remains of the territory in the graphic representation?

4. The irreducible

Every subway map has its own set of rules, style and aesthetics, raising inevitably the question which components of the public transport network remain constant in its diverse tran-

scriptions. Subway maps are partly a representation of reality (or, in my words, a transcription of reality) and partly a product of their designers (a construction). With Krämer (2012a: 157), one could argue that 'representation and production' are not mutually exclusive, but the one includes the other, although I cannot be sure whether the concept of 'including' gets to the heart of the matter.

An initial issue concerns the way reality reveals itself in a subway map. Perhaps we need to revisit the discussion in the second section. There we noticed that the topography is not completely banished from the map. Is that an indication of reality? Real locations still play a certain role as supportive information in terms of manageability and orientation. For example, the element 'river' serves as a reference.

Likewise, relations between other elements serve as references. This results in creative necessities which we can characterize as *irreducible*. These irreducible necessities result from topographical conditions and cannot be explained other than by a pre-existent reality, whose relations are reflected in the maps. Occurrences such as overlaps of routes or relative positions to waterways must be correctly represented relationally, according to the topography of the area. Whether what we see in the map is indeed the correct representation of a relation, we only come to confirm when we reach our destination with the help of the map. Let us picture a map in which the *Oporto* interchange station was on the same side of the Rio Manzanares as the *Acacias* interchange station, and that the two stations were to be just one stop apart (see Figure 25). Obviously, the navigation does not work just because there is a map that lists the stops in this way. After a while, I realize that *Acacias* is not on the same side of the river as *Oporto*, even though the map says so. This map would only be correct if it were a fact beyond all conceivable maps – correct and incorrect – that *Oporto* and *Acacias* are on the same side of the Rio Manzanares and only one stop away from each other.[3]

Some components of the map are fictitious, though, or derived from previous graphical decisions. A curve in the representation of the course of the river, not present in reality, owes its existence to the fact that the course of the metro lines has been given privilege and the course of the river has to fit in. The river as a marginal feature adopts the design rule of the privileged metro lines (only horizontal and vertical lines). As a result, there are several right angles that do not really belong there, but only serve to maintain the correct relation to the metro line. Fictitious design features connect with representational features in the representation, but both can be identified separately. Krämer (2012a: 162), rightly states that 'only through the invention and creation of artificial, "idealistic" facts such as the meridians or the equator [...] can we represent spatial relationships of the real world on the map in the form of a relational image'.

One could go so far as to say that the creation of invented graphical aids is a proof that the image exists and vice versa. It would not be possible to recognize a construction as such if it did not contain something that was not constructed. Any reference to the constructedness and cultural situatedness of a given representation must acknowledge, even if grudgingly, that

there is something to be represented in the first place. The argument that leads to this insight can be called an 'argument from facticity' (Gabriel 2013: 147). It states that even a constructivist position needs to make realistic premises at some point. At some point, according to Markus Gabriel, absolute facts must be introduced. The fact that from looking at the map I can and must – if I want to navigate successfully – draw conclusions about the reality of the metro network, shows the inevitability of the representation of facts.

Figure 25. Imaginary metro map of Madrid where *Oporto* station appears on the same side of the Rio Manzanares as the *Acacias* station and one stop apart instead of two

Conclusion

The Madrid metro network can never be seen in its entirety other than in the synopsis of schematic maps. These are artifacts created for the purpose of navigation. But since there are no clear specifications for their design, there are many different possible representations. Going along with Nöth, I could understand the different formal imaging methods as *styles*. He defines styles as 'the difference between alternative messages that a code allows for selection' (Nöth 2000: 398). Different representations of the same object are not necessarily semantically identical. Instead, both likenesses and differences of meaning are to be found. Maps that serve the same purpose are alike in that they have a 'common semantic core' that can be identified as the relations between the elements. In addition, however, differences come into play, as shown in the 14 variables listed above.

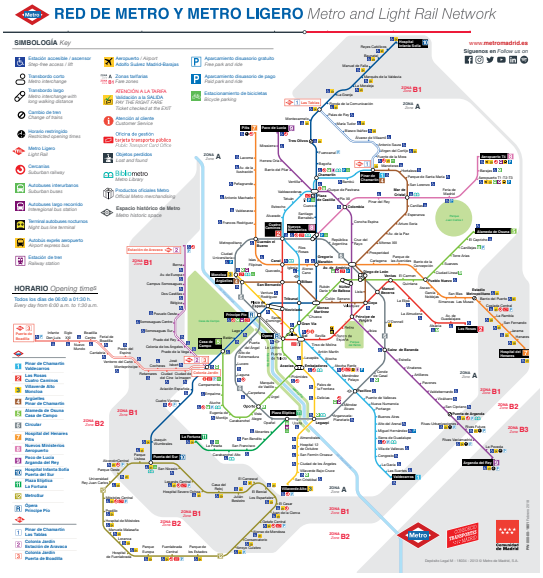
The reader of a subway map is not interested in the design of the map and its methods or

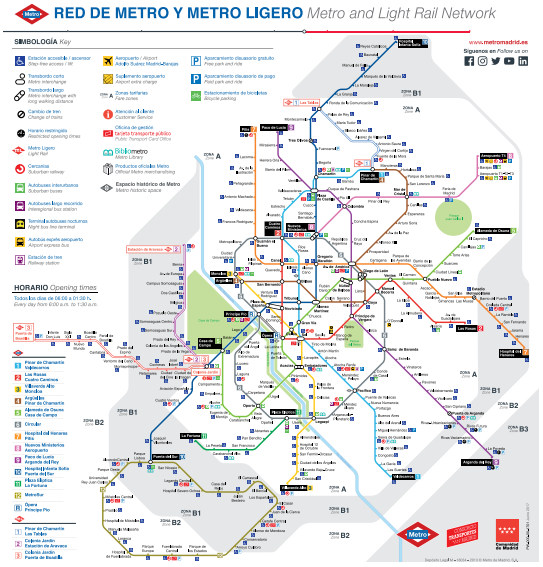
styles, but rather in the depicted reality, which by reading the map provides her with options for action. Although the image seems to be secondary, it is ultimately the instance that makes navigation on the map possible through information – and is thus identifiable as a constitutive condition for *action* in the local public transport network (if not for the local public transport network itself). If navigation succeeds, the map can be described as 'right' or correct', based on a functionalist perspective that does not say anything about the extent to which the variants themselves have different effects on actions. It is obvious that the variants are semantically different, for example, in providing different background information (sometimes the river is marked, sometimes it is not, sometimes the line courses roughly follow topographical conditions, sometimes they strictly go at right angles). Different angles, colors, or line weights may be semiotically underdetermined, but the fact that they do not convey *specific* coded information does not mean that they do *not* convey *any* information.

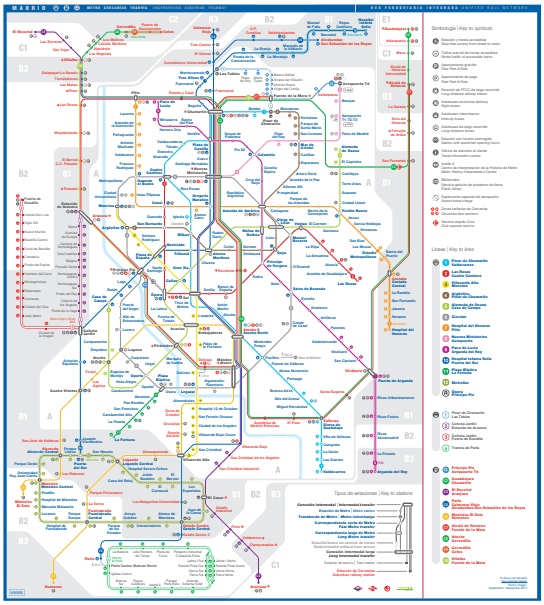
The difference at play here could be conceptualised, according to Schlichtmann (2017: 43), as the dichotomy between immediate and indirect meaning, denotation and connotation. The former is directly linked to perceptible objects, the latter only indirectly, by allusion. The many variants I encounter point to the fact that there can be no unproblematic representation in the sense of an *immediate* representation. The visibility of the map is therefore not a given factor, but is based on an aesthetic-graphic process, which, right from the beginning, is a constitutive part of the production of information. Let us return once more to the paradox of cartographic modeling, first encountered in Eco's map example. With regards to subway maps, this example suggests that the practicability of a subway map is constituted by its dissimilarity. Indeed, the clarity of particular information is increased if other, more general information is obscured.

Maps show that in terms of efficiency the schema is superior to the detailed image. The key to this is their symbolic character in the graphic elements of subway maps, there is an epistemic surplus value laid out, compared with what is represented or coded by them. In this sense, a map is to be understood as a cognitive design whose purpose is to make reality accessible, although it uses elements that cannot be derived from real-world references, but that as graphical inventory, graphical aids and conventions are highly contingent. The design of the map and its inner coherence is therefore not solely based on the organization of real-world content, but derives its form primarily from the genuine specifications of the graphic inventory and its design rules.

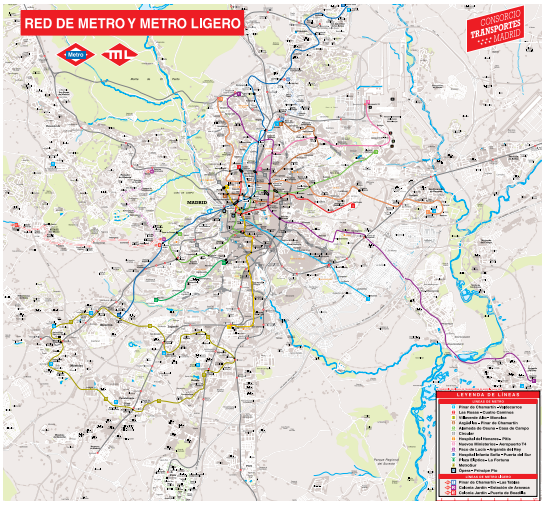
Figures 2-21. Twenty Madrid metro maps issued between May 2007 and April 2018

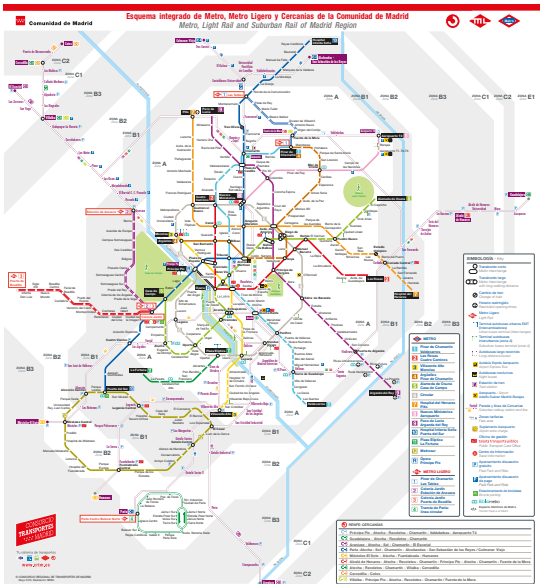




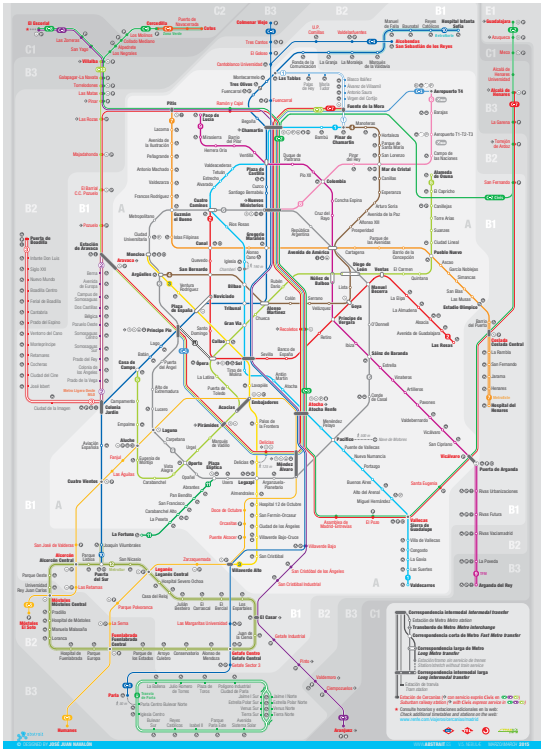



Metro
Comunidad de Madrid
PLANO DE LA RED DE METRO DE MADRID


RED DE METRO Y METRO LIGERO
CONSORCIO TRANSPORTES MADRID


Esquema integrado de Metro, Metro Ligero y Cercanías de la Comunidad de Madrid
Metro, Light Rail and Suburban Rail of Madrid Region
Comunidad de Madrid
CONSORCIO TRANSPORTES MADRID


MADRID




PLANO DE BOLSILLO
Pocket map


Plano turístico / Tourist map


MADRID


Líneas
Simbología
Plano esquemático de la red
Metro Ligero
Metro


Red de Metro de la Comunidad de Madrid
Madrid Region Metro Network


Red de Metro y Metro Ligero
Metro and Light Rail Map


Red de Metro en el municipio de Madrid


Red de Metro y Metro Ligero
Metro and Light Rail Network

NOTES

1 Bertin mentions the two dimensions of the plane; the size; value; texture; color; orientation; and shape (1983: 7).
2 Unless the user sees him/herself in the tradition of the Situationist International.
3 Oporto is situated to the west and Acacias is situated to the east of the river "Rio Manzanares" and they are actually four stations apart from each other.

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