The Cartographic Journal *Vol. 52 No. 2 pp. 193–203 International Cartographic Conference, Rio 2015 - Special Issue May 2015*

REFEREED PAPER

How Do Map Readers Recognize a Topographic Mapping Style?

Jérémie Ory[1,2], Sidonie Christophe[1,2], Sara Irina Fabrikant[3] and Benedicte Bucher[1,2]

[1]Institut National de l'Information Géographique et Forestière (IGN), COGIT Lab., 94165 St Mandé, France. [2]Paris-Est University, 5 bd Descartes, Champs-sur-Marne, 77454 Marne-la-Vallée, France. [3]University of Zürich, Department of Geography, Winterthuresrstr. 190, CH-8057 Zürich, Switzerland
Email: Jeremie.Ory@ign.fr

The process of reading a topographic map requires users to recognize and learn the cartographic symbols of the key (or legend) while interpreting the territory as depicted on the map at a given level of abstraction (the form and nature of features, their saliency and relationships). We present the results of an empirical user study that aims to identify and assess the main graphical characteristics that are used by map users to recognize the design principles which constitute the topographic mapping style adopted by IGN (Institut National de l'Information Géographique et Forestière), France. Our results suggest that 91% of the participants were able to recognize an IGN-France topographic map amongst other topographic map products. We also determine which graphical characteristics play a role in the recognition of this cartographic style, either by visual memory or by visual perception, and identify the representation of relief, including contour lines and shaded relief, as one of the major graphical characteristics of the topographic mapping style of IGN-France. Moreover, the participants of our study considered the representation of touristic POI (points of interest), toponymy, typography, the main roads network, the individual buildings and the forests, to be essential for stylistic recognition.

Keywords: topographic map style, map perception and cognition, empirical study, graphic semiology

INTRODUCTION

Stylized views of geographical space enable users to interpret and analyse information (e.g. the relative importance of paths and roads) at a given scale more efficiently than other views, such as satellite imagery. Cartography is the science of communicating information about geographical space based on visual representation (Robinson, 1960). For instance, topographic maps covering a country are produced by National Mapping Agencies (NMAs) and are based on a conceptual model of topographic features and their portrayal through graphical choices (styles). The process of reading a topographic map requires users to recognize and learn the cartographic symbols of the key (or legend) while interpreting the territory as depicted on the map at a given level of abstraction (the form and nature of features, their saliency and relationships). This process involves several cognitive capacities, like perception, recognition and visual analysis. Wood (1993) and Kent (2005) suggest that the understandability of a map is not only supported by the key, but also by its overall visual cartographic design as a particular combination of specific visual variables applied to cartographical data. Brunet (1987) shows that cartographic language is composed of the form, layout, and significance of the distribution shown by the map. Moreover, Kent and Vujakovic (2011) apply the cartographic language paradigm to further explain stylistic diversity in topographic mapping. However, a new issue has emerged in recent years: the efficiency of topographic maps and users' ability to recognize, learn and decode the maps' abstraction of a geographical space, in a context where topographic maps are no longer a 'well-known' series produced by a NMA but may be designed by various producers and combined together (Hoarau *et al.*, 2013).

According to Kent and Vujakovic (2009), the notion of 'style' is closely related to the concept of recognition of certain 'similarities within a group and the recognition of differences to these outside that group'. These similarities convey some 'visual proximity' between maps and make it easier for a reader familiar with one map to read the others. Indeed, if a good map design optimizes the reading and thinking processes of map readers, it can be assumed that the users' performance of visual queries and tasks would be improved if such users are familiar with some visual characteristics in the map: they categorize them, consciously or not, to belong to a 'group', referring not only to data and confidence in the map, but also to what they already know, or what they have been learning, through their experience of topographic maps and geographical space. Formalizing topographic styles as families of design principles would be an opportunity to enhance map efficacy, when, for instance, adding new information to an existing topographic map, designing

DOI: 10.1080/00087041.2015.1119459

new maps at larger scales, or when mixing heterogeneous data from producers and individual mapmakers.

Therefore, our long-term aim is to understand how people learn and use styles of topographic mapping, as families of map design principles, for reading such maps more efficiently. Our approach, in addressing the issue mentioned above, involves studying how readers first recognize families of cartographic design principles. In the next section, we first review existing literature related to topographic styles and the categorization of maps and map design principles, in order to define the concept of 'topographic style'. The following section presents an empirical study to identify the recognizable and representative graphic characteristics of the topographic style of IGN-France. Finally, we present and discuss the results of the empirical user test.

TOWARDS A DEFINITION OF TOPOGRAPHIC STYLE

We attempt to arrive at a definition of the concept of 'topographic style' in considering the notion of 'family of map design principles'. We therefore review some related research and propose a framework that synthesizes knowledge about topographic style.

Related research on defining cartographic styles

To organize the review of related work, we rely on a generic definition of 'style' taken from the Oxford English Dictionary[1]. Three basic explanations are highlighted as follows: (1) a particular procedure by which something is done; a manner or way; (2) a distinctive appearance, typically determined by the principles according to which something is designed; and (3) elegance and sophistication. The ingredients of this general definition are very relevant to addressing the issue introduced in Section 1, and particular focus will be given to the aspect of 'visual appearance' (as per explanation '(2)' above).

Ingredient (1), 'a particular procedure', is related to the production process, i.e. the technical choices made by the NMA to design their maps – data selections, cartographic generalization, symbol specification, and so on – in order to represent their geographical spaces (Duchêne *et al.*, 2011). The diversity of cartographic styles amongst NMAs is partly due to the distinctive design of their map symbols (Kent and Vujakovic, 2009; Bucher *et al.*, 2010). Indeed, the map producer uses some low-level visual detectors present in the set of visual variables that Bertin (1967) recommends in order to express efficiently geographic information to map users. Groupe μ (1992) explains that image interpretation is very dependent on the medium chosen to transmit the information, and the targetted receiver, i.e. map readers and their experience and motivation. Much research exists concerned with describing maps in the sense of an objective (aim) and how to meet this objective (specification of a production and rendering process). Amongst others, Bucher *et al.* (2007) propose to represent explicitly the intention of a map designer in terms of scale, represented features, relationships between the features, and reading modalities (to be seen at first sight versus to be read).

Ingredient (2), 'a distinctive appearance', is related to elementary visual characteristics which constitute this appearance, not only derived from the previous ingredient, but also derived from the particular user model (experience of maps and geographical spaces, perceptual and cognitive processes, and so on).

Cartographic processes are managed regarding the spatial and semantical characteristics of the geographical spaces. The cartographic visual scene is influenced by the depicted geographical context (such as urban areas, water features, mountains, and so on), the spatial distribution of different landscape features and theirs depictions (shape, texture, colour, and so on). The combination of abstraction processes finally provides a particular visual composition in the map, based on graphic features, such as the colour and shape of road networks, the colour and texture of vegetation cover, and the colour and shape of the built environment. According to specific visual properties they may have (e.g. spatial structures, contrasts, visual saliency), some graphic features or some combinations of graphic features may be particularly identifiable and distinguishable by a map user.

Figure 1 below illustrates how the three components – geographical context, spatial distribution, and visual characteristics of features – give a meaningful visual hierarchy to the map, notably guided by some particular saliency between features, assigned by the map producer, according to the purpose of the map.

We define a graphical characteristic by those salient graphic features that stand out to the users, because of their colour, form, texture, spatial distribution, and so on. A graphical characteristic emerges from the organization in sequences and groups of all graphical signs contained in the map composition. In this sense, we also consider a graphical characteristic as a visual stimulus (Goldstein, 2010), facilitating the reading and visual interpretation of the cartographic composition and the apprehension of the geographical space by the map users. The graphical characteristics, as visual stimuli, influence the map users' visual perception and memory. Indeed, the visual appearance of a cartographic composition is encoded and stored in their brain through experience of use. In this sense, theories of visual perception and cognition thus are important to consider in definitions of cartographic styles. Gestalt Theory provides the basis on how we perceive and understand a visual scene. This theory is based on the idea that users try to organize what they see into figures that sit in the foreground

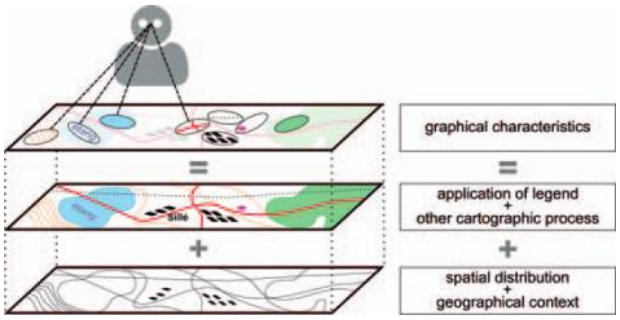

Figure 1. Design [by National Mapping Agencies (NMA)] and perception (by users) of graphical characteristics

of a visual scene, separated from a background, according to a number of 'laws'. Gibson (1977) extents the Gestalt theory, introducing the term of 'affordance'. The concept of affordance is based on the presence of graphical signs in the scene, offering (*affording*) the opportunity for the users to perform an action. Moreover, according to Ware (2008), salient graphical features, i.e. 'low-level detectors' such as form, orientation, filling, and so on, allow viewers to detect visual characteristics in an image.

In a previous work (Ory *et al.*, 2013), we identified specific graphical differences between topographic map products from two particular NMAs, IGN-France and Swisstopo, based on a systematic comparison, as illustrated in Figure 2 below. The salient graphical characteristics may be perceived at first glance by users: we suppose that they allow them to recognize a map product through its particular topographic style. Nevertheless, these graphic characteristics are not clearly explained, neither in the specification of the intended map nor in the production process. Furthermore, ingredient (1) above does not systematically capture all parameters leading to the identification or recognition of the particular graphic characteristics of a cartographic style.

In order to assess the visual appearance of maps, much research has attempted to categorize maps and to extract related criteria. In order to measure the stylistic diversity of state topographic maps amongst European countries, Kent and Vujakovic (2009) systematically analyzed a sample of twenty 1:50,000 topographic maps each produced by a different European NMA, based on the maps' content and appearance. They created a multi-level classification of the symbology used to represent themes in topographic mapping, such as 'built-up area', 'vegetation', and 'hydrology'. Their approach suggests that the diversity of European topographic styles is partly due to differences in cartographic representation which arise both from cartographic processing (for instance, generalization) and from symbol specifications. Their final results indicate a high degree of stylistic diversity throughout Europe. Moreover, with the application of a cluster analysis, the authors identify a number of groups of similar European topographic styles; with the French and the Swiss topographic map falling into the same group, which was tentatively labelled the 'Alpine style'. Beconyte (2011) visually compared a variety of map types in order to identify their graphical styles, divided into decorativeness, expressiveness, and originality. Based on these categories she classified a range of maps into different styles: artistic, antique, laconic, expressive, and so on. Christophe (2012) provided various approaches (visual categorization, topographic style specification, and transfer from an artistic style to a topographic style) to formalize and model a topographic style. She emphasizes that being able to manage cartographic styles during the map design process should enhance users' creativity and improve map quality.

Ingredient (3), 'elegance and sophistication', is related to the emotional or aesthetic response that can be experienced by users (related to ingredient '2') and the graphical characteristics that can be controlled during the map design process according to what the producer attempts to achieve (related to ingredient '1').

The visual appearance (ingredient '2') provides an emotion, a feeling, and an aesthetic response, as addressed by Kent (2005), and Fabrikant *et al.* (2012), amongst others. Jolivet (2009) and Bucher *et al.* (2010) show that the application of different symbol specifications from many European countries to the same cartographic dataset produces various topographic depictions with different graphical appearances, which in turn influence the users' perception of colour (for instance, drab versus luminous) and of feelings or confidence (for instance, realistic versus artistic, untidy versus accurate). These emotions, feelings or aesthetic responses may be controlled during the map design process, according to the related abstraction processes the cartographer may manage, i.e. colour specification (Chesneau, 2007; Christophe, 2011), artistic stylization (Christophe and Hoarau, 2012; Christophe *et al.*, 2015) and level of realism/abstraction (Hoarau *et al.*, 2013).

Modelling a unifying framework

In order to study the efficiency of the map reading process, it is necessary to synthesize the theoretical advances made by the recent research outlined above through the creation of a unifying framework. The model shown in Figure 3 represents each ingredient composing a family of design principles.

This model also addresses an important aspect: to use visual appearance as a style parameter for formalization even though visual appearance might change over time. In particular, we notice the changes in map design techniques (i.e., moving from print production to digital-database-driven methodologies) or the changes in the map producer's intentions (i.e. evolution of map purpose and use for the military to public use). Thus visual appearance may vary little over time, and such changes might produce topographic maps with different graphical identities.

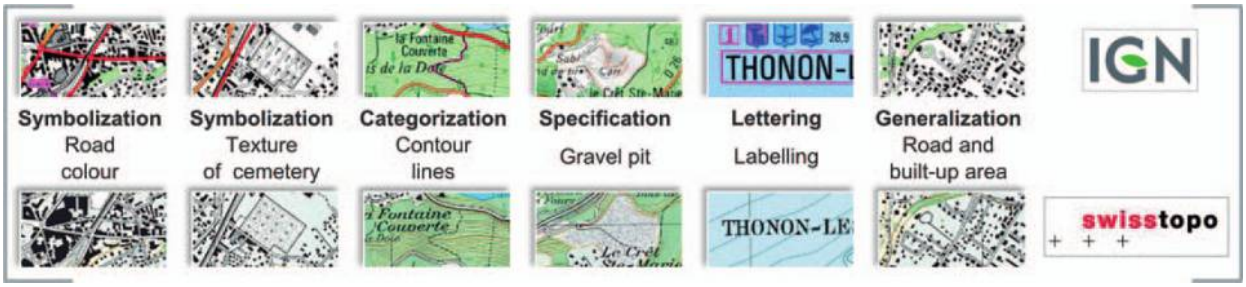

Figure 2. A comparison of graphical characteristics between topographic maps of the same scale: Institut National de l'Information Géographique et Forestière (IGN)-France and Swisstopo

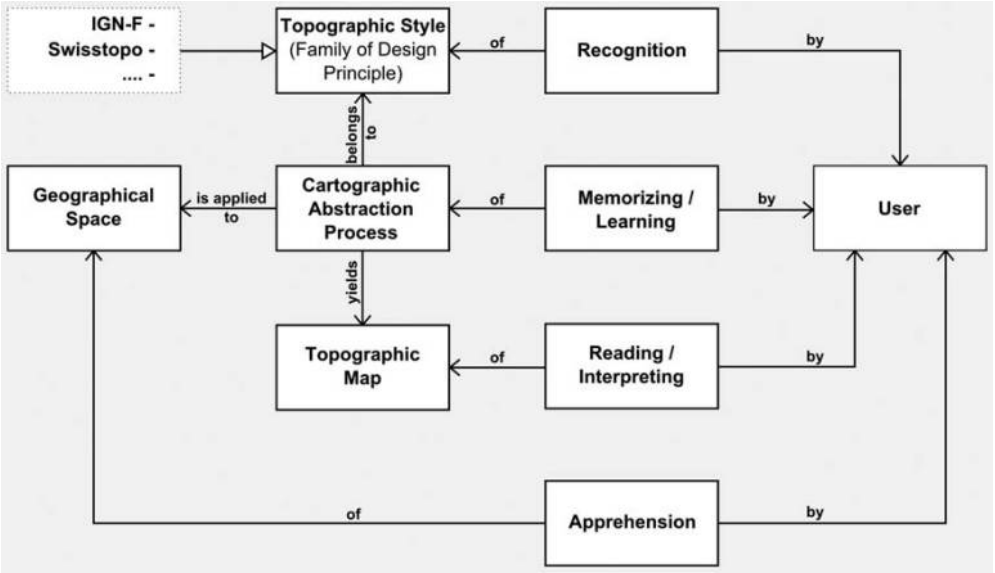

Figure 3. Proposed unifying framework to synthesize knowledge from recent research into the design of topographic maps: how users read them to enrich their apprehension of a geographical space, from underlying design principles

Figure 4 below illustrates the visual appearance of two 1:25,000 IGN-France topographic maps over time.

To keep some consistency in delivering the cartographic message to users over time, the producers of topographic maps have established consistent mapping practices. These are notably guided by some general and technical specifications (Ruas, 2006) which lead to the notion of a family of design principles. One might thus distinguish visual characteristics that remain constant over time, such as colour choices to distinguish between different feature types, e.g., black for cultural features (including buildings, railways, and so on), green for vegetation (such as wooded areas, orchards, and vineyards), orange and white to depict different road network categories, blue for water features, and white for the background. Certain constancy in the visual appearance of a map can be identified, and we believe that users learn this way of depicting geographical space through their map-reading experience. We also believe that the graphical characteristics directly identified by the users allow them to recognize a family of design principles, i.e. a topographic style. To tackle this issue, we conducted an empirical user experiment with a view to formalizing the

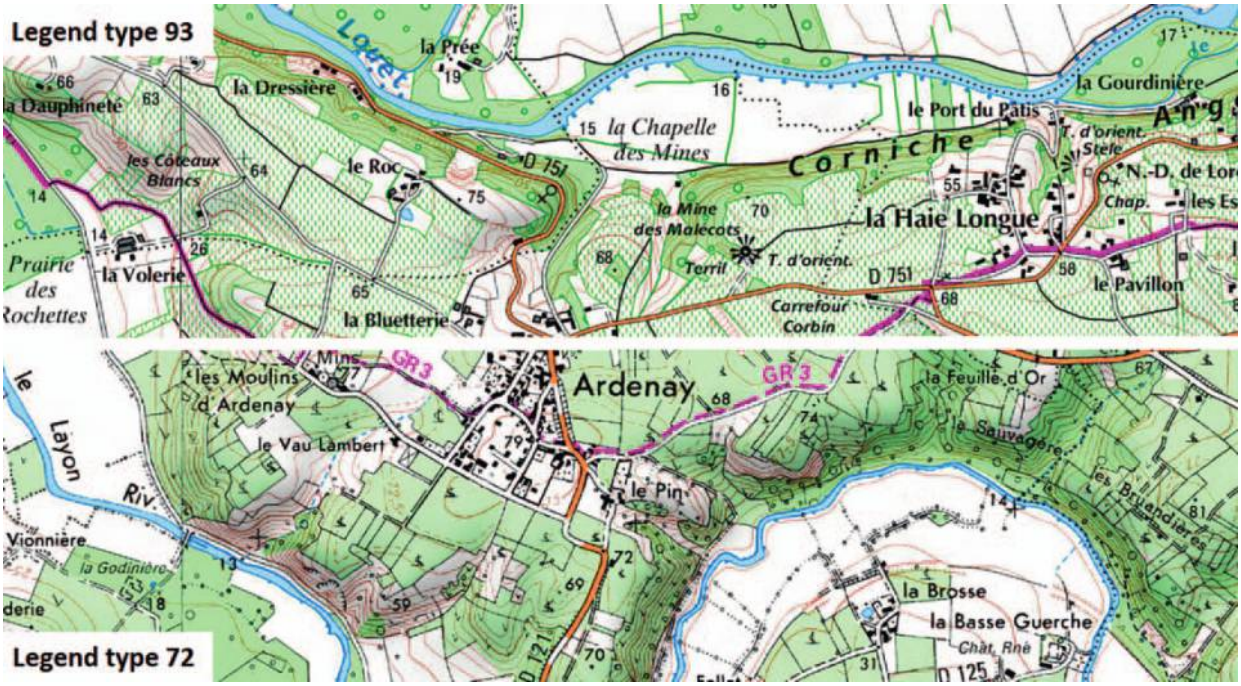

Figure 4. Two different types of Institut National de l'Information Géographique et Forestière (IGN)-France symbology, indicating change over time (IGN® copyright)

topographic style of IGN-France from the user's ability to recognize it, by identifying some representative graphical characteristics. We chose the very popular 1:25,000 topographic map series of IGN-France, which is the most widely used topographic map in France, and is therefore expected to be well known by French map users.

EXPERIMENT: ASSESSING THE GRAPHICAL CHARACTERISTICS OF THE TOPOGRAPHIC STYLE OF IGN-FRANCE

This section describes an experiment which aims to assess the relevance of the concept of topographic style introduced in the previous section, specifically, whether users learn and recognize topographic styles and how this may be achieved.

Practically, in alignment with related studies, we focus on a certain style that is represented in the topographic map series of a specific NMA, in this case, produced by IGN-France. We also concentrate on users that may be especially familiar with such a style because they regularly work with maps: cartographers, researchers, professionals, and so on. We decided to mainly involve French people in an attempt to keep the level of knowledge and experience of the IGN-France maps generally consistent. The experiment aims to test the following hypotheses:

- (H1) Users are able to recognize the IGN-France topographic style among others and to determine whether a map or a cartographic symbol belongs to this style or not;
- (H2) Some map properties play a major role in how users identify and recognize a topographic style;
- (H3) As map symbols, some types of feature are more effective than others for the identification and recognition of a topographic style.
- (H4) During the map's reading, the mechanism for the recognition of a topographic style is based on two steps: (1) users identify some graphical characteristics as representatives and (2) compared them with the graphical characteristics learned from past experience of topographic maps reading.

Materials

First, a French expert in cartography (i.e. an expert in producing and using maps and with a familiarity of the French landscape and territory) selected various topographic maps produced by NMAs depicting various parts of the world, including seven from IGN-France, two from Swisstopo (Switzerland), one from Ordnance Survey (UK), one from the Cartographic Institute of Catalonia (ICC, Spain), one from the Land Registry and Topography Administration (Luxembourg), and one from the Land Information of New-Zealand (LINZ). All topographic maps were of a scale comparable to 1:25,000. This selection of maps helps participants to focus on aspects of visual appearance for the experiment. In order to reduce the influence of language used for toponymy (place names), the maps designed by Swisstopo and by ICC (Spain) depict French territories and the IGN-France 1:50,000 map depicts an Italian territory.

Second, the same expert manually extracted some graphical characteristics from several digital 1:25,000 IGN-France topographic maps, which they considered as representative of the visual content of a 1:25,000 IGN-France topographic map. They highlight certain graphic choices made by the cartographer, such as the level of generalization and symbolization, combined with the spatial structure of the related geographical space. Figure 5 below shows these graphical characteristics on a white background in identical manner as in a 1:25,000 IGN-France topographic map, representing the following geographic themes:

- *relief* (relief shaded and contour lines) in sample 1;
- *roads network* in sample 3 (main roads), sample 10 (secondary roads), and sample 16 (local roads);
- *built environment* in sample 7 (central urban zone), sample 12 (individual buildings), sample 14 (industrial zone) and in sample 4 (landmarks);
- *vegetation cover* in sample 6 (hedges), sample 8 (forests) and sample 15 (orchards);
- *hydrography* in sample 2 (channels and marshland) and sample 9 (hydrographic surfaces) *toponymy* in sample 11; *tourist information* in sample 5 (touristic routes) and sample 13 (touristic points of interest).

These were shown to the participants as visual stimuli to assess the IGN-France topographic style in the experiment.

Procedure

The full experiment comprised eight groups of questions. In this paper, we focus on two question groups (the entire test protocol is described in Ory et al.(2014).

In the first group of questions, the participants have to identify a topographic map among others and specify which features have been used to identify it. This first group determines whether participants are able to correctly recognize IGN-France style amongst that of the other NMAs, and which criteria were used most often. We displayed six topographic maps designed by different NMAs: two maps from IGN-France (1:25,000 and 1:50,000) and four other topographic maps, one each from ICC, Swisstopo, ACT, LINZ. We then asked the participants to identify which map is designed by IGN-France NMA (question 1). The goal of this question is to validate the hypothesis H1, i.e., whether users are able to recognize IGN-France style among others and to determine whether a map or a cartographic symbol belongs to this style or not. Then, in question 1.2, we proposed five criteria to the participants which we considered important in the recognition of a topographic style:

- the displayed geographic features;
- the graphic appearance of the depicted features;
- the level of cartographic generalization of the map;
- the toponymy used in the map;
- the selected geographic footprint.

We asked the participants to assess each of these criteria according to how they help users to recognize the topographic style of IGN-France among that adopted by other NMAs. In this sense, the participants assign a score for each criterion according to three values: most important,

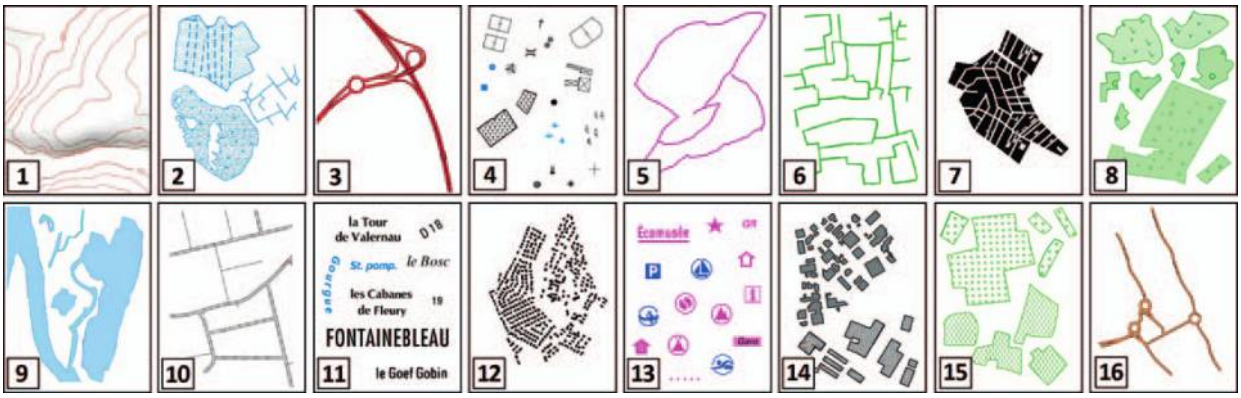

Figure 5. Graphical characteristics extracted from Institut National de l'Information Géographique et Forestière (IGN)-France 1:25,000 topographic map series (IGN® copyright)

somewhat important and not important. The goal of this question is to validate the hypothesis H2, i.e., whether some map properties play a major role in how users identify and recognize a topographic style. In question 1.3, to complete this assessment on visual appearance, we asked the participants to evaluate the visual importance of the symbolization of six different cartographic themes which (we assume) allow them to recognize the topographic style of IGN-France:

- symbolization of roads network;
- symbolization of hydrographic features;
- symbolization of vegetation cover features;
- symbolization of build-up areas;
- labelling style;
- representation of relief.

The participants assigned a score for each criterion according to three values: most important, somewhat important and not important. The goal of this question is to validate the hypothesis H3, i.e., as map symbols, whether some types of feature are more effective than others for the identification and recognition of a topographic style.

In the second group of questions, the participants have to identify and select which graphical characteristics (as per Figure 5) are mainly representative of an IGN-France topographic map. In question 2.1, the participants have to select the four most representative graphical characteristics of the style of IGN-France without seeing IGN maps, thus relying on their memory or previous knowledge of IGN-France maps. The goal of this question is to test the hypothesis H4.2, i.e., whether the mechanism for the recognition of a topographic style is based on remembrance (from past learning). It is important to emphasize that the graphical characteristics were selected by participants without their specifying any order of preference. In question 2.2, the participants selected the four most representative graphical characteristics of the topographic style of IGN-France by visualizing four maps of IGN-France. This attempted to identify what was visually representative of the maps that had been seen. The goal of this question being to test the hypothesis H4.1, i.e., whether users identify some graphical characteristics as representatives during the map's reading.

Participants

The experiment was first broadcast online during the 26th International Cartographic Conference in Dresden and second on a mailing list about Geography[2]. We sought to reach expert participants, e.g., those having a certain level of experience of producing and using maps for leisure or work purposes, and therefore likely to possess a high-level ability in reading, interpreting and recognizing maps. Professional mailing-lists in geography and cartography, and the international conference in cartography, were therefore used to recruit participants. Moreover, the mailing lists are mainly French-speaking and participants generally come from, or know, the French landscape and territory.

Four hundred and ten participants (43% female) took part in this user-study. On average, participants were 35 years old and ranged between 18 and 85 years, with 72% of the participants reported to conduct research in cartography or in a related discipline and 30% considered themselves to be advanced or experts in cartography. Participants came from 24 different nations, with 85% from France and 10% from other European nations. We decided to request mainly French people in order to manage a certain level of knowledge and experience of the IGN-France maps.

RESULTS, ANALYSIS AND DISCUSSION

For each group of questions, we analyse statistically the results in order to highlight the graphical characteristics used by participants to recognize, characterize and identify a topographic map produced by IGN-France. Then, we apply the main representative graphical characteristics (identified in the experiment) to a cartographical dataset, in order to visualize and analyse the resulting judgements of what is representative in IGN-France maps, by visual memory or by visual perception.

Criteria which enhance recognition of the topographic style of IGN-France

In question 1.1, 14% of participants selected only the 1:25,000 map from IGN-France and 0.5% of participants selected only the 1:50,000 map from IGN-France. In addition, 30% of participants selected the 1:25,000 map from IGN-France and at the same time the map from Swisstopo and/or the map from ICC, depicting French

territories. Finally, the 1:25,000 IGN-France map was selected by 91% of participants, i.e. alone or in addition to others, and was better recognized than the 1:50,000 IGN-France map. Only a few participants (16%) correctly selected the two maps from IGN-France. These results show that the 1:25,000 IGN-France map is clearly the most representative map of the IGN-France style for users. Nevertheless, the Swisstopo and ICC maps depicting French territories were also selected and considered to be IGN-France maps, which suggests that the language used in the toponymy and the depicted geographical space are both important criteria. With these results, it remains difficult to prove whether the recognition of the 1:25,000 IGN-France topographic style is high.

For question 1.2, 80% of participants considered the graphic appearance of the depicted features as the most important criterion, above the cartographic generalization level of the map (47%) and the toponymy (33%). While the graphic appearance of depicted features is the most important criterion, we believe that the level of cartographic generalization plays a more significant role in the recognition of a topographic style for the expertise of these participants when compared to the general expertise of the wider population. Moreover, because of their recognition of the language used by the toponymy, the participants selected an IGN-France map 'a priori' as such maps use the French language.

For question 1.3, 62% of participants considered the representation of relief as the most important criterion, above the symbolization of built-up area (48%) and the roads network (47%). We consider these three cartographic objects as the major elements leading to the definition of a topographic map: relief + built-up areas + roads network. Moreover, given their importance, the representations of these three cartographic objects have a 'visual structuring effect' on the map's appearance, allowing users to recognize its topographic style. It is also worth noting that the labelling style is considered the most important criterion by 40% of participants, which is relevant to the results of the previous question, where toponymy was considered as an important criterion by 33% of participants. We notice that the language used for the toponymy (question 1.2) seems to be less important than their typographic style (question 1.3).

We wish to know whether the participants will identify the same cartographic objects in the following question.

Graphical characteristics which represent the topographic style of IGN-France most effectively

Figure 6 below shows the percentage of participants which selected the four most representative graphical characteristics of IGN-France style without seeing IGN maps (question 2.1) and a statistical analysis of these results in four groups[3].

The first group represents the most representative graphical characteristics for participants:

- relief (sample 1).

The second group comprises two graphical characteristics, which participants consider as highly representative, by importance order:

- touristic points of interest (POI) (sample 13)
- toponymy and typography (sample 11).

The third group comprises six graphical characteristics, which participants consider as moderately representative, by importance order:

- forests (sample 8);
- landmarks (sample 4);
- channels and marshland (sample 2);
- individual buildings (sample 12);
- main roads (sample 3);
- orchards (sample 15).

The fourth group comprises six graphical characteristics, which participants consider as few representatives, by importance order:

- industrial zone (sample 14);
- secondary roads (sample 16);
- hydrographic surfaces (sample 9);
- touristic routes (sample 5);
- central urban zone (sample 7);
- local roads (sample 10);
- hedges (sample 6).

Figure 7 below shows the percentage of participants which selected the four most representative graphical characteristics of IGN-France's topographical style in visualizing four maps samples (question 2.2) and a statistical analysis of these results in four groups[3].

The first group comprises the three most representative graphical characteristics for participants, by importance order:

- relief (sample 1);
- main roads (sample 3);
- touristic POI (sample 13).

The second group comprises two graphical characteristics, which participants consider as highly representative, by importance order:

- individual buildings (sample 12)
- forests (sample 8).

The third group comprises two graphical characteristics, which participants consider as moderate representative, by importance order:

- toponymy and typography (sample 11);
- orchards (sample 15).

The fourth group comprises nine graphical characteristics, which participants consider as few representatives, by importance order:

- landmarks (sample 4);
- channels and marshland (sample 2);
- touristic routes (sample 5);
- industrial zone (sample 14);
- central urban zone (sample 7);
- secondary roads (sample 16);
- hydrographic surfaces (sample 9);
- local roads (sample 10);
- hedges (sample 6).

We note that the representation of relief, i.e. contour lines and relief shaded, and the touristic POI are considered as

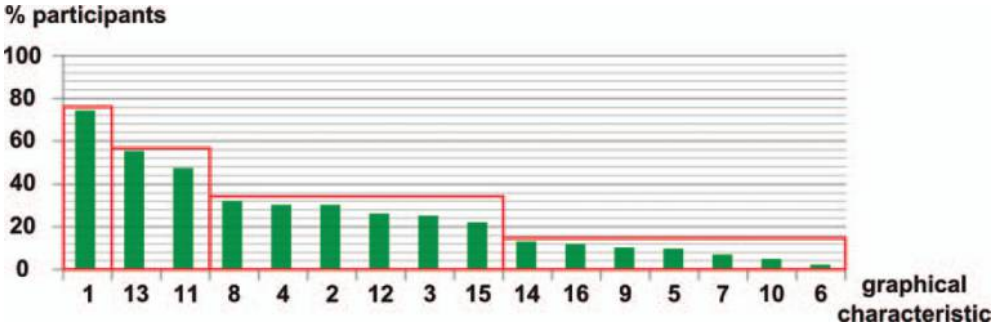

Figure 6. Bar chart representing graphical characteristics selected by participants without seeing maps: visual memory

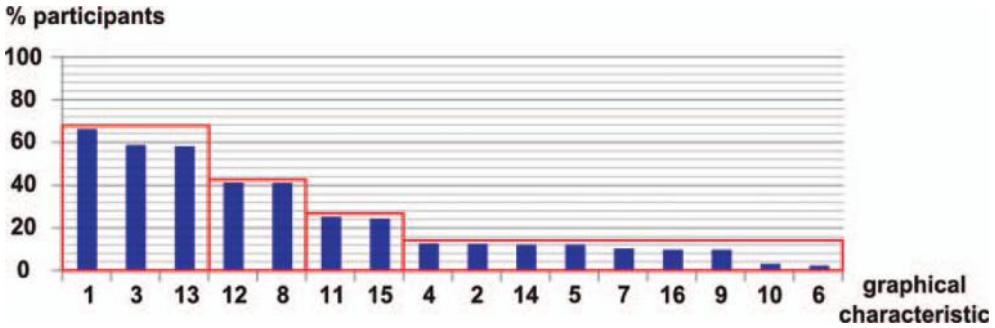

Figure 7. Bar chart representing graphical characteristics selected by participants in visualizing four maps: visual perception

essential graphical characteristics to recognize the 1:25,000 IGN-France topographic map in the two cognitive tasks (visual memory and visual perception). Moreover, the representation of relief has a predominant role for the participants, because it is considered as the major graphical characteristics by the participants in the two cognitive tasks. Second, the importance given to the main roads and the toponymy and typography vary in visualizing the four map samples. It seems that the depicted geographical space influences the choices of participants, probably because of the presence of a structuring road network in one or several given map samples.

Visualization of the main results using a cartographic dataset

According to the main representative graphical characteristics identified in the experiment, we applied them to a cartographic IGN-France dataset in order to visualize the mental image (by visual memory and by visual perception) that the participants have of the IGN-France style.

The map on the left of Figure 8 shows the application of the three most representative graphical characteristics (the first two groups of analysis) selected by participants in the visual memory task, and so in retrieving what is stored in their memory: representation of relief (1), touristic POI (13) and toponymy (11). We consider these graphical elements to form a basis of knowledge for style recognition that is highly important for users, because it is stored in the memory by the participants.

The map on the right of Figure 8 shows the application of the five most representative graphical characteristics (the first two groups of analysis), selected by participants in the visual perception task, in identifying what is most important: representation of relief (1), main roads (3), touristic POI (13), individual buildings (12) and forests (8). These visually salient elements, highlighted by this cartographic representation, could be described through two main criteria: colour and form. Colour: used by IGN-France to symbolize some features, notably the pink of touristic POI and the green of forests; the form and the spatial distribution of certain features: the individual buildings, which seem visually prominent because of their individual form and the distribution of all features; both colour and form: main roads, which seem to be an important structuring graphical element of the map.

If we analyse comparatively these two maps, we distinguish that some graphical characteristics are common between them: representation of relief and touristic POI. We suppose that these graphical characteristics are interpreted by the users, as a graphical signature of the cartographical language used by the producer. Indeed, these graphical characteristics are perceived but also stored in the memory by users. Moreover, the map on the left represents the IGN-France memorized style, i.e. what the users learn of the design principle used to express geographic information. Indeed this map highlights elements which are stored in the user's memory. The map on the right represents the IGN-France style as perceived and summarized by the users. This map highlights cartographic elements which are graphically salient and allow the user to quickly interpret the design principles of the NMA. A filter process is carried by users from the map on the right to the map on the left. We note that the language used by the representation of toponymy is important for users, indeed it allows them to locate the map and to identify its producer.

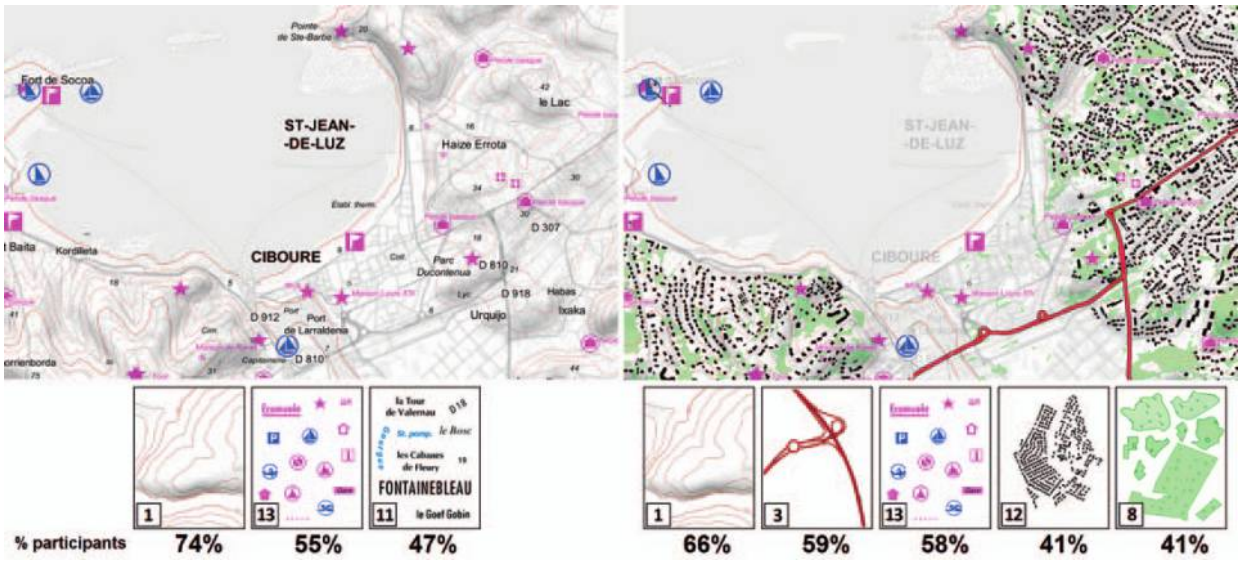

Figure 8. Cartographic results, by application of the most and highly representative graphical characteristics identified in the experiment (the first two groups). The left map corresponds to the visual memory; the right map corresponds to visual perception (IGN® copyright)

DISCUSSION

Through their map-reading experience, users learn some of the design principles used by NMAs, leading to the 'concept' of topographic style. We identify that some graphical characteristics have a better perception and memorization to others, due to their properties (i.e. form, colour, structure, and distribution). From the analysis of our results, we identify four major groups of information contained in the map:

- *signature information*, corresponding to the common graphical characteristics, is the most representative of the two cognitive tasks (representation of relief and touristic POI). We suppose that this information allows the users to recognize the design principles of the map producer.
- *visual salient information*, corresponding to the graphical characteristics, is visually salient, due to their colour and form or their spatial distribution: representation of the main roads, built-up areas and forests). We suppose that this information allows users to read and interpret more efficiently the topographic map.
- *located information*, corresponding to the toponymy and typography. We suppose that this information is semantically salient and allows the users to locate it in the space-image.
- *secondary information*, corresponding to the rest of the graphical characteristics contained in the map and assessed as less representative or non-representative of cartographic language used by the producer. These graphical characteristics don't help the users in recognizing the topographic style of the map.

If we consider only the most representative graphical characteristics, i.e. the relief representation, the reading and the understanding of it in a topographic map require some knowledge and some experience of maps; it would be interesting to reproduce this visual test on non-expert participants to compare the obtained results. In addition, as the sample of relief representation was shown to the participants first (placed at the first rank on the set displayed), it would also be interesting to show other characteristics to the users first to check whether the expected results are identical. We should also emphasize that the obtained results are also dependent on the extraction of graphical characteristics. This step brings a bias in our study, even if we consider our selection of graphical characteristics as an expert selection.

Moreover, concerning the individual buildings and the main roads, they seem to be considered important for the users due to their graphical saliency. The form and the spatial distribution of these cartographic features are important parameters in the generalization process used by the map producer in order to preserve their original form and a consistent spatial distribution of the real world, allowing the user to directly distinguish and recognize them. This kind of cartographic features seems belonging to a particular group, by given a special visual impact on the map and allowing the recognition of a geographical space. In this sense, the content of the map, i.e. the geographical space depicted by the map, becomes an important parameter in the map's visual appearance and hence in the formalization of topographic style, as stated by Kent and Vujakovic (2009).

Finally, our experiment aims to identify which graphical elements contained in the map are representative of its style for users, and to try to identify which of these are first and directly perceived and which are stored in the user's memory. With this experiment, we deduce that the users are able to identify what is visually representative and salient for them. In order to test the relevance and resilience of our method, it would be interesting to compare our results with those obtained in an automatic method of saliency detection (Touya *et al.*, 2015).

CONCLUSION & PROSPECTS

In conclusion, we have proposed a unifying framework for understanding topographic mapping style and examined a key aspect of this framework: the ability of readers to recognize a

topographic style and the mixed processes of map reading and learning styles involved in such recognition.

Our protocol has relevance for the identification of the graphical characteristics of NMA style. In this paper, we identify the graphical characteristics which formalize the visual appearance of IGN-France topographic style: representation relief, touristic POI, main roads, individual buildings, toponymy and forests.

This experiment brings some new insights to understanding the parameter of visual appearance regarding the notion of topographic style, as introduced by Ory *et al.* (2014), in which further hypotheses are tested. Moreover, through this experiment, comparing the characterization of IGN-France topographic style, by visual perception and by visual memory, we are able to distinguish which graphical characteristics are representative in each cognitive task. We can now begin to understand how a user visually perceives and visually memorizes an IGN-France topographic map.

These results bring some insights into how users perceive the graphical symbols that constitute the cartographic language of a particular map producer, which allow readers to recognize a topographic style. In addition to suggesting how symbol designs can be developed by recommendations regarding the application of visual variables, these results also suggest how the legibility of the topographic map might be improved as well as the efficiency of the cartographic message that is communicated to its users.

Our findings will be pursued in analysing the user's selection of graphical characteristics in different geographical contexts. Moreover, to improve our experiment it would be interesting, first, to allow open responses about what are representative of topographic style, and second, to enrich the procedure in independently analysing the criteria 'colour' and 'cartographic features'. One approach would be to give test participants the option to specify which colours and features are significant (or not) when recognizing topographic style. In this sense, the participants would be able to manipulate the visual elements to include in or exclude from the family of design principles. With these future studies, we hope to identify the exact parameters of visual appearance of the IGN-France maps related to the depicted geographical space and to formalize a more comprehensive model of topographic map style.

BIOGRAPHICAL NOTES

After completing a Bachelor's degree in geography and a Master's degree in GIS, Jérémie Ory is currently a PhD student in the COGIT Laboratory – Cartography & GISciences – at IGN-France. His thesis work consists in analyzing the design and the perception of topographic depictions in order to formalize knowledge on the recognition of topographic styles.

ACKNOWLEDGEMENTS

We would like to offer our sincere thanks to all participants for taking part in our experiment. We would also like to thank those who reviewed our manuscript for their detailed and thoughtful comments. This work is granted by the French National Research Agency, with the reference ANR-12-CORD-0025.

NOTES

[1] http://www.oxforddictionaries.com/definition/english/style or http://www.merriam-webster.com/dictionary/style

[2] https://sympa.unil.ch/wws/info/geotamtam

[3] The number of classes was determined by the Sturges calculation method and their classification using Jenks natural thresholds. The number of classes was determined by the Sturges calculation method and their classification using Jenks natural thresholds.

REFERENCES

Bertin, J. (1967). **Semiology of Graphics: Diagrams, Networks, Maps**. University of Wisconsin Press, 1983 [first published in French in 1967, translated to English by Berg, W.J. in 1983].

Beconyte, G. (2011). 'Cartographic styles: criteria and parameters', **Proceedings 25th International Cartographic Conference, (ICC'11)**, 3-5 July, Paris, France.

Bucher, B., Jolivet, L., Buard, E. and Ruas, A. (2007). 'The need for web legend services', in **7th International Symposium on Web and Wireless GIS (W2GIS)**, Lecture Notes in Computer Science, Springer ed. by Ware, J. M. and Taylor, G. E., pp. 44–60.

Bucher, B., Mustière, S., Jolivet, L. and Renard, J. (2010). 'Adding metadata to maps and styled layers to improve map efficiency', in **INSPIRE Conference 2010**. 22-25 June, Krakow, Poland.

Brunet, R. (1987). **La carte mode d'emploi**, Fayard/Reclus, Paris/Montpellier.

Chesneau, E. (2007). 'Improvement of colour contrasts in maps: application to risk maps', **10th AGILE International Conference on Geographic Information Science**, Aalborg, Denmark.

Christophe, S. (2011). 'Creative colours specification based on knowledge (ColorLegend System)', **The Cartographic Journal**, 48(2), pp. 138–145.

Christophe, S. (2012). 'Cartographic styles between traditional and original (towards a cartographic style model)', **Proceeding of Auto Carto Conference 2012**. Columbus, OH, USA.

Christophe, S. and Hoarau, C. (2012). 'Expressive map design based on pop art: revisit of graphic semiology?', **Cartographic Perspectives**, 73, pp. 61–74.

Christophe, S., Hoarau, C., Boulanger, L., Turbet, J. and Vanderhaeghe, D. (2015). 'Automatic rendering of a Cassini style', **27th International Cartographic Conference (ICC'15)**. Rio de Janeiro, Brasil.

Duchêne, C., Christophe, S. and Ruas, A. (2011). **Generalisation, symbol specification and map evaluation: feedback from research done at COGIT laboratory, IGN France, International Journal of Digital Earth, 4(Suppl. 1**, pp. 25–41.

Fabrikant, S., Christophe, S., Papastefanou, G. and Maggi, S. (2012). 'Emotional response to map design aesthetics', **Proceedings of Giscience Conference 2012**. 18-21 September, Columbus, OH, USA.

Gibson, J. (1977). 'The theory of affordances', in **Perceiving, Acting, and Knowing**, ed. by Shaw, R. and Bransford, J., pp. 67–82.

Goldstein, E. B. (2010). **Sensation and Perception**, Cengage Learning, Andover.

Groupe μ. (1992). **Traité du signe visuel**, Seuil, Paris.

Hoarau, C., Christophe, S. and Mustière, S. (2013). 'Mixing, blending, merging or scrambling topographic maps and orthoimagery in geovisualizations?', **Proceedings 26th International Cartographic Conference (ICC 2013)**. Dresden, Germany.

Jolivet, L. (2009). 'Characterizing maps to improve on-demand cartography – the example of European topographic maps', **Proceedings of 17th Conference on GIScience and Research in UK (GISRUK'09)**, Leeds, United-Kingdom.

Kent, A. J. (2005). 'Aesthetics: a lost cause in cartographic theory?', **The Cartographic Journal**, 42/2, pp. 182–188.

Kent, A. J. and Vujakovic, P. (2009). 'Stylistic diversity in European state 1:50 000 topographic maps', **The Cartographic Journal**, 46/3, pp. 179–213.

Kent, A. J. and Vujakovic, P. (2011). 'Cartographic language: towards a new paradigm for understanding stylistic diversity in topographic maps', **The Cartographic Journal**, 48/1, pp. 21–40.

Ory, J., Christophe, S. and Fabrikant, S. (2013). 'Identification of style in topographic maps, in poster proceedings', **26th International Cartographic Conference (ICC 2013)**. Dresden, Germany.

Ory, J., Christophe, S. and Fabrikant, S. (2014). 'Caractérisation visuelle d'un style topographique', **Proceedings International Conference SAGEO**. 24-27 November, Grenoble, France.

Robinson, A. H. (1960). **Elements of Cartography**, John Wiley & Sons Inc., New York.

Ruas, A. (2006). **Usages des bases de données géographiques – exemple de l'IGN**, Rencontre Jacques Cartier, Lyon, France.

Touya, G., Christophe, S. and Hoarau, C. (2015). 'Clutter and map legibility in automated cartography: a research agenda', **Cartographica** (in press).

Ware, C. (2008). **Visual Thinking for Design**. Morgan Kaufman.

Wood, M. (1993). 'The user's response to map design', **The Cartographic Journal**, 30/2, pp. 149–153.