A STUDY ON MENTAL REPRESENTATIONS FOR REALISTIC VISUALIZATION THE PARTICULAR CASE OF SKI TRAIL MAPPING

R.Balzarini [a], A. Dalmasso [b], M.Murat [c]

[a] Inria Grenoble Rhône-Alpes, 655 Avenue de l'Europe, 38330 Montbonnot, France-raffaella.balzarini@inria.fr
[b] Laboratoire de Recherche Historique Rhône-Alpes 14, avenue Berthelot, 69363 Lyon, France - anne.dalmasso@upmf-grenoble.fr
[c] Université Pierre Mendès France, 151 Rue des Universités, 38400 Saint-Martin-d'Hères, France- muratmaxime15@gmail.com

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ABSTRACT:

This article presents preliminary results from a research project in progress that brings together geographers, cognitive scientists, historians and computer scientists. The project investigates the evolution of a particular territorial model: ski trails maps. Ski resorts, tourist and sporting innovations for mountain economies since the 1930s, have needed cartographic representations corresponding to new practices of the space. Painter artists have been involved in producing ski maps with painting techniques and panoramic views, which are by far the most common type of map, because they allow the resorts to look impressive to potential visitors. These techniques have evolved throughout the mutations of the ski resorts. Paper ski maps no longer meet the needs of a large part of the customers; the question now arises of their adaptation to digital media. In a computerized process perspective, the early stage of the project aims to identify the artist-representations, based on conceptual and technical rules, which are handled by users-skiers to perform a task (location, wayfinding, decision-making) and can be transferred to a computer system.
This article presents the experimental phase that analyzes artist and user mental representations that are at stake during the making and the reading of a paper ski map. It particularly focuses on how the invention of the artist influences map reading.

1. INTRODUCTION

1.1 Context

This article aims to present the preliminary results of the MECOMO[1] project. It is a work in progress collaboration between geographers, cognitive scientists (INRIA-GRA), historians (LARHRA) and computer scientists (LIG), around the study of the evolving representation of a territorial model: the design of ski resort trail maps.
From a historical point of view, it is part of the revival of studies on the history of territories and innovation, especially applied to the mountain, in coordination with the work of the International Society for Alpine History. It contributes to the current broadening of historical sources and to the setting up of new multidisciplinary approaches.
The cognitive approach of the project aims to restore the practice of this representation over time and thus in the evolution of a socio-geographic system (ski resorts). From a geo-cognitive point of view the project takes up the challenge to grasp the cognitive mechanisms underlying the production and interpretation of these plans.
From an IT point of view the project takes up the challenge of modernizing the paper support. The digitalization of real-time information, the immersive environments, the scalable applications, are technological paths to explore, in order to respond more adequately to the new practice in winter sports.

1.2 Related works

The project fits into current studies coordinated mainly by the "Commission on Mountain Cartography of ICA". It is based on findings about semiotic categorization of mountain panoramas (Patterson, 2000, Tait, 2010). Trails maps for ski areas are iconic images of the sport of skiing and its relation to the terrain on which ski resorts are built. The development of the maps has paralleled the development of lift-served skiing. The combination of bigger areas to map and an increase in money in the sport led to a shift from simple wayfinding maps to more elaborate mountain portrayals (Patterson, 2000). Artists have employed three main types of views for ski mountain: planimetric, profiles and panoramas maps. Planimetric views are images viewed from directly above all portions of the skiing area. Profile views are generally very simple elevation views of the mountain from a very low oblique angle or ground level that have little or no three-dimensional character and look into the mountain with little or no perspective. Panoramic views are by far the most common type of map: they are oblique perspectives of any angle and they often are not topographically accurate.
Patterson (2000) notes, in discussing the work of Heinrich Berann (1915-1999), one of the earliest panoramic mountain ski map painters, that with a panorama, "something truly magical happens. Readers feel drawn into the panorama as if they were flying high above the land." The panoramic ski map may be particularly evocative of the mountain terrain for skiers, for whom the image may replicate the feeling of flying down the mountain on skis. Panoramas respond to the desire for resorts to look impressive to potential visitors. Ski areas often ask for the mountain to "look bigger" and for the artist to distort the mountain for this purpose. This request can pose a serious challenge that in some cases is resolved by local distortion of the mountain terrain and camera view (Patterson, 2000).
Landscape artists have addressed such challenges by applying local deformation to map objects in hand-painted hiking and skiing panoramas. Using digital means, the painters' techniques may be translated into geometry deformation algorithms for digital panorama creation (Field, 2010) and (Jenny *et al*., 2010).

[1] "MECOMO – MEmory, COgnition and MOdelling of mountain landscape"

An algorithmic solution based on inverse distance interpolation and moving least squares have been developed. Based on the observation of Berann's techniques, this solution should help the cartographer to deform a digital terrain model by intuitively manipulating the surface in a 3D display. Digital imitation of the techniques of panorama painters have been also improved by combining local terrain deformation and progressive bending algorithms with painterly rendering methods for panoramas (Bratkova *et al*. 2009) and (Jenny *et al*., 2011).
Relying on these findings, our approach looks rather to the evolution of the use of ski maps by skiers and this according to a cognitive perspective. The project finds its added value in the search for cognitive responses to the current use of ski trail maps; we intend to improve on the topic with the support, among others, of current research associated with emotional mapping (Griffin, 2012) and with expressive map design (Christophe *et al*., 2012).

1.3 Overall issue

Though the research on panoramas and ski maps has been extensively detailed in the US, as far as we know, there were no scientific projects on this topic in France.
Our case study concerns mountain representations according to the artistic style of the "*Atelier Novat*"*,* the pioneer French ski mapmaker that uses the panoramic view.
The Atelier Novat was born in the '60s, founded by Pierre Novat. At the time, Pierre was a young decorator, freshly graduated from 'Beaux Arts' school and did not yet know that he would become the French standard for mountain panorama. In the early 60s, he lived in Val d'Isere and he was asked by the sport director to make an addition to the resort panorama initiated by Berann, because the later was overbooked. In '64, Berann being increasingly occupied by the Swiss and Austrian resorts, Pierre was entrusted with the ex-novo creation of Courchevel resort panorama: it is the beginning of a 35 years career and a production of 250 panoramas. Arthur, Pierre's son, grew up amid brushes, maps, aerial photos and tracing paper, and pursutes the activity of his father. It was only in the early 90s that he brings the computer into the atelier and starts a production of illustrated panoramas.
Likewise other "panoramic" artists, the *"Atelier Novat"* artists bring their expertise to combine in a single mountain panorama, the objects of the landscape which are not visible in a real angle of view: the panorama is realistic, easy to read, but subtly distorted. Figure 1 shows an example of ski trail maps in French Alps, Alpes d'Huez ski resort; it is made by Arthur Novat from *Atelier Novat.*

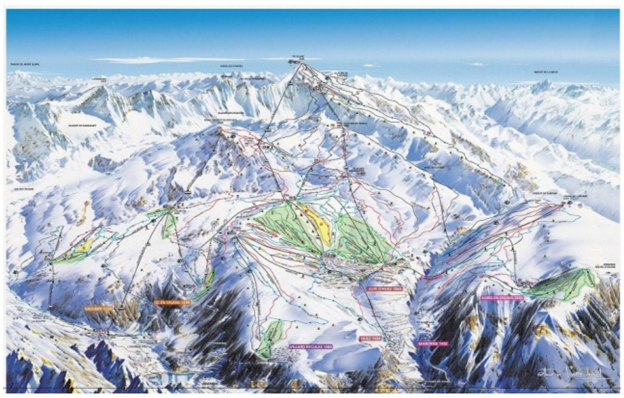

Figure 1. Alpes d'Huez ski trails maps, made by *Atelier Novat*

Ski maps are built from land morphology, local knowledge, and marketing applications. The resulting representation seems to provide common readable information. They are actually related to practices of space which ever changing in time and which require regular adaptations to their representations.
According to some mountain operators, paper maps no longer meet the needs of a large part of the customers; the question now arises of their adaptation to digital media (iPhone, tablets).
At present, the Atelier Novat only sporadically make some modifications on maps of ski resorts with whom he likes to work. Its market has been largely taken over by companies linking digital mapping (GIS) to mobile Apps. Despite the more modern look of these solutions, they are based on the same principle, initiated by panoramic artists, which consist in the information layer overlay on a landscape background.
The final aim of our project is an innovative response to the adaptation of paper ski maps to digital media: a software development for interactive, customizable, editing ski trails maps. The software should be able to generate *a digital immersive environment (following the « Novat artistic style») starting from the place where the skier is situated.* This specific feature is essential to make a difference between the allocentric view provided by the paper map and egocentric view supported by the 3D environment.

2. METHODOLOGY

In a computerized process perspective for designing ski trails maps, our exploratory approach will aim to answer the main research questions:
1. Are the artist and user's mental representations the same?
2. What representations make ski maps effective to perform a user's task?
3. What representations can be reproduced in a computer system?

The methodology presented in this article focuses essentially on the initial query (1) while recommendations will be suggested for the other questions (2) and (3). This early stage of the survey concerns the analysis of the artist-expert and users-skiers mental representations.
Human activity is based on mental representations that are actually personal reconstructions of the "reality" made by the subject, based on his perceptual systems and previous knowledge. Both internal (cognitive) and external (graphics, language or physical) representations provide the forms in which information can be structured, stored, analyzed, understood and communicated to (NRC, 2006). The internal spatial representation for handling spatial images in the brain requires spatial skills such as visualization, orientation and spatial relations (Egarty et *al.,* 2006). The external spatial representation refers to the organization, interpretation and communication of information with maps, charts or images.
In order to identify the mental representations deployed by the artist for making ski maps and by the skiers for understanding paper ski map, an experimental protocol was set up. Its design consists:
1. At first we analyze the design and production rules in ski maps, graphics (representations) which result and the related information that the expert thinks can be inferred.
2. Then we analyze use practices of ski maps, the graphics observed by the skier and information he uses to perform a task.
Comparing this information, provided and used, allows us to identify expert-representations that are handled by users while reading the map.

2.1 The experimental protocol

Mental representations can be identified through the study of verbal data that is collected and analyzed according to "protocol analysis" (Ericsson, 2006) and (Simon, 1972), and "verbal data analysis" techniques (Chi, 1997).

In the protocol analysis method, to obtain *think-aloud protocols,* the subjects are asked to verbalize the information they attended to while solving a problem. The focus is to capture the *processes* of solving a problem or making a decision (i.e. doing some task).

In the verbal data analysis method, to obtain *explaining protocols,* the subjects are asked to verbalize explanations, descriptions, justifications, and rationalizations. The focus here is to capture the representation of the knowledge that a solver/user has and less the processes of problem solving.

In our case study, knowledge was represented over the practical application of spatial analysis concepts and cartographic design. Complementarity of both techniques provides data corresponding to all the concepts, objectives, roles and relationships mobilized by a subject when performing a task. These techniques are commonly used in psychology to reconstitute a cognitive structure, they apply both to the study of expertise and to the study of user behavior.

2.1.1 The experimental protocol to study expert-artist activity

Expertise can be understood from an information-processing perspective by focusing on the role of knowledge, its content, and the cognitive processes that bring that knowledge to bear during problem solving (Chi, 2010). To understand how an expert works, we need to understand how knowledge is represented, organized and structured (Chi, 2006). This implies that a set of "messy data" (sketches, diagrams, videos and audio recordings) (Chi, 1997) is collected.

Participant: the expert-artist, Arthur Novat, 60 years old and CEO of the company Atelier Novat.

Modalities: we observed Arthur Novat in "ecological conditions," when *making a ski map* (case study: Alpes d'Huez in the French Alps, see Figure 1). He was interviewed according to thinking-aloud and explanation techniques during 3 hours and 20 minutes.

Material: the artist could use color pencils, paper, ski plans archives from "Atelier Novat" and a PC.

Data: video-audio recording of the interview was transcribed. Sketches illustrating the global process of creation with the rules of constructions (invariants, concepts and operations) were also collected.

2.1.2 The experimental protocol to study user-skier activity

Skiers' knowledge and heuristics can be determined by listing a set of propositions, a set of concepts, a set of goals, or a set of rules from "what" he said (the content). However, to explore the knowledge, the researcher must then assess the relations among such a set.

Participants: we observed 20 subjects to perform a task (including location, wayfinding, decision-making), when *reading the ski map.* Subjects were between 18 and 65 years old, 12 women and 8 men. They were distributed into 3 groups according to their ski level: 2 subjects in the novice skier group (C1), 10 subjects in the intermediate group (2) and 8 in the advanced group (C3). Ski level was defined by auto-evaluation according to the "Ecole de Ski Français' standards". They were also spread into 2 groups according to 2 different ski map resorts: Alpes d'Huez (see Figure 1) and Villard de Lans, (see Figure 2) situated in the French Northern Alps.

Figure 2. Villard de Lans-Corençon ski trails maps, made by *Atelier Novat*

Ski maps of these two ski resorts have been chosen because representative of the regional ski resorts in terms of size (large and medium) and attendance. Subjects were not familiar with these ski resorts.

Modalities: subjects were observed in "controlled conditions" supported by the same semi-structured interviews, based on operational assumptions. The interviews include an interpretation step of the map in which the salient elements are explained (map objects, focal points ...) and a decision making step in which two routes have to be plotted on the map: one to achieve a specific goal (restoration on ski runs) and the other to explore the ski area. They were interviewed according to thinking-aloud and explanation techniques.

Material: paper ski maps in real formats and felt pens were given to the subjects to depict their ski-paths and underline salient graphical elements.

Data: we collected sketches, drawings and about 15 hours of video audio recording, which were transcribed.

Further data from experimental campaigns in "ecological conditions" for skiers are also planned in the fall (2015): users will be observed in real ski resort with ski map and wayfinding, decision-making tasks to perform.

Visual data from the eye-tracking will be analyzed with statistical approaches.

2.2 Data analysis

Data analysis primarily concerns verbal data that representing the largest volume of our corpus. Verbal analysis is a methodology for quantifying the subjective or qualitative coding of the *contents* of verbal utterances. The method of coding and analyzing verbal data consists of the following main steps:

1. Reduce or sample the protocols, that is, reduce data by selecting a particular activity;
2. Segment the reduced or sampled protocols;
3. Develop a coding scheme (taxonomic categories scheme);
5. Depict the mapped formalism.

We present hereafter as we have adapted these instructions to our survey. Once the corpus to be coded was decided, we then had to segment the verbal utterances to identify the unit of analysis. The defining cut can occur at many points, revealing units of varying granularity, such as a proposition, a sentence, an idea, an interchange as in conversational dialogue, or an

episode. In the segment protocols we searched for verbatim, tags or keywords, such as “mountain” or “valley”, “ski track” or “names of localities”, “green, red” “and so on, in order to form semantic groups which design conceptual categories.
The coding scheme we developed is a taxonomic categories scheme. The units of analysis are organized on a taxonomy founded on the characterization of tasks, actions and (graphics) objects. An o*bject* describes the temporary grouping of a collection of visual features together with other links to verbal-propositional information (Kahneman *et al*., 1992) and (Ware, 2008). Figure 3 shows an excerpt of the segmentation of the corpus.

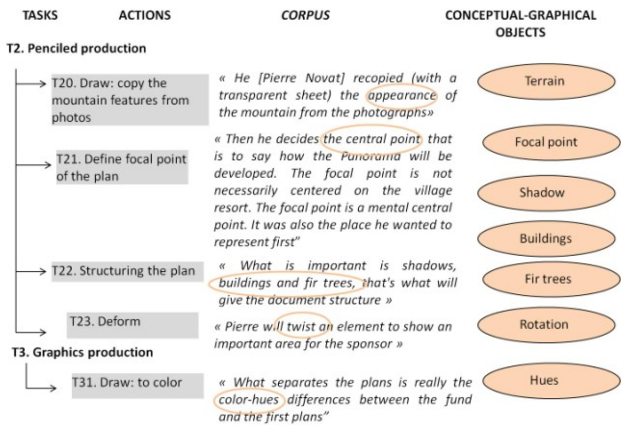

Figure 3. An excerpt of utterances segmentation from expert’s activity analysis (Arthur Novat’s corpus)

Verbal data analysis was also supported by sketch and drawings analysis. The matching of speech elements (*verbatim*) and drawings can confirm that a graphic and conceptual object has been used by the subject.

3. PRELIMINARY RESULTS

Analysis from verbal data and from sketches led to qualitative results. These results include the identification of rules (1) in expertise procedure and user practice (2), graphic objects organized in taxonomy of conceptual categories and information arising from the graphics (3). We present the details below.

3.1 Main results for rules identification

The identification of the conceptual and technical procedure *of making ski plan* is synthesized in Table 1. Procedural rules are coded and classified into tasks and actions. Two successive proceedings are displayed: in Table 1 Pierre Novat’s procedure which covers the creation of the panorama *ex-novo,* it dates from '80 -'90 and is now completed; in Table 2 Arthur Novat procedure, which inherits the rules of Peter, mainly concerns changes in panoramas and which is carried out, from the 90s, through digital tools.

Pierre Novat main procedure rules for making ex-novo ski plans

Code	Task	Code	Action
T0	Demands	T00	analyse marketing demands
		T01	create an overall view of the area
		T02	*devise : mental deformation*
T1	Design	T10	read and interpret the general staff maps or IGN maps
		T11	*built mental deformation*
		T12	take aerial and ground photographs
T2	Penciled production	T20	draw: copy the mountain features from photos
		T21	define focal point
		T22	stucturing the plan
		T23	*deform : spin, stretch, reduce*
		T24	validate with the sponsor
		T25	add ski lifts trails
T3	Graphic production	T30	draw : set up colors
		T31	validate with the sponsor
		T32	make photos output
T4	Slopes and trails overlay	T40	trails drawings
		T41	overlay films trails

Table 1. Mainly rules for making ski plans from Pierre Novat activity

Arthur Novat main procedure rules for modify ski plans

Code	Task	Code	Action
T0	Demands	T00	analyse marketing demands
		T01	enlarge an area or a zone
T1	Design	T10	read and interpret the general staff maps or IGN maps
		T11	*devise*
		T12	analyze Google Earth
T2	Make changes	T20	draw: make a sketch
		T23	*deform : spin, stretch, reduce*
		T24	validate with the sponsor
T3	CAD drawing	T30	draw : duplicating some parts of terrain
T4	Slopes and trails overlay	T40	trails drawings

Table 2 Mainly rules for making ski plans from Arthur Novat activity

The T0 and T1 tasks constitute the preparation steps to drawing: they are very conceptual and driven by the concepts of "vision", "heuristic" and "invention". For instance: the notion of "vision" is illustrated, according to the verbalizations of the artist expressing concepts of view, as frontal vision, flight vision, changing viewpoints and perspectives..., the notion of "heuristic" is illustrated through the knowledge and the experience of the land; the «invention » is the response to the "marketing" demand, and it is illustrated by comprehensive vision techniques such as local terrain deformation, rotation, vertical exaggeration. This invention takes shape through the creation of illusions: being very familiar with the territory, “I [A. Novat verbatim] rather prefer to invent”. He adds credible but not real elements in the map … in short, *he invents the territory*. **“**In a ski trail map such as Alpes d'Huez, the invention is permanent”. To depict ski lifts links “it is better that the link is not geographical or topographical, but it is a visual and moral relationship"[A. Novat verbatim].
Tasks T2, T3 and T4 correspond to the implementation of these concepts through drawing techniques.

Use practice process (*reading and interpreting the ski plan*) is obviously much simpler than that of production and the two are not comparable. This generic procedure allows us to identify the moments of this practice where the plan is a real support for decision making. The various actions correspond to objectives and we will see how reading and understanding the graphic objects facilitates (or don’t) achieving these objectives. Table 3 shows use practice generic process.

Basic rules for ski map using procedure			
E1	**Get start**	E11	define a departure point
		E12	define a point of arrival
E2	**Define itineraries**	E21	assess the landscape and pleasant places
		E22	assess the difficulty of the ski runs, length and capacity of ski lifts
		E23	find networks connections
		E24	find break places
		E25	find panorama places
E3	**Decide of the return pathway**	E31	find easy ways to get to the starting point

Table 3.Generic rules in use practice of ski plans

Now, what binds the two procedures is handling of graphic objects and of the transmitted information.

3.2 Main results for graphics' recognition

The identified graphic objects, resulting of verbal data and sketch analysis are organized in 5 taxonomic categories that we defined and for which we give details below. These five categories group the objects explained by the expert and the objects mentioned by skiers.

1. Geography.
1.1 Domain boundaries
1.3 Sunlight exposure, orientation (shadows contrast)
1.4 Focal point

2. Geomorphology
2.1 Terrain profile
2.2 Peaks and ridges
2.3 Slopes (stiff, craggy …)
2.4 Corridors
2.5 Hollows, combes
2.6 Rocks, cliffs
2.7 Fir trees
2.8 Snow and ice (hues variance)

3. Tracing
3.1 Colored ski runs
3.2 Ski runs geometry
3.3 « Green » areas
3.4 Ski lift

4. Structures
4.1 Pictograms
4.2 Buildings
4.3 Roads

5. Nomenclature
5.1 Names of the ski runs
5.2 Names of the ski lift
5.3 Elevation values
5.4 Toponyms

A detail of some types of graphics present in a ski map is given in Figure 4. This picture is not in the real format of the ski map, it was magnified for cares of visibility.

Figure 4. A detail depiction of graphic objects present on a ski map. Detail of the Alpes d'Huez from Atelier Novat

3.3 Main results for rendering information

The results here show the information the artist-expert intends to convey through his work and the information that is interpreted by a skier (subject) to make decisions. We retained any information discussed at least once within the corpus of verbal data.
The results are organized in tables (Table 4 to Table 8) by taxonomic categories, graphical object, for the expert and for skiers' level groups (C1, C2 and C3).The cells of the same color indicate that the information inferred by the expert corresponds roughly to that understood by the skiers.

1. GEOGRAPHY				
Graphics	**Expert**	**Skiers by ski level**		
		C1	**C2**	**C3**
1.1 Domain boundaries	Overview, scope	Overview, scope	Overview, scope	Overview, scope
1.2 Orientation and sunlight exposure, (shadow contrast)	Give sham exposure (east-west)		Look for real orientation	Look for real orientation
			Estimate snow quality	Estimate snow quality
1.3 Focal point	Center of the picture	Center of the ski resort	Center of the ski resort	Center of the ski resort

Table 4. Information from geographical graphics

2. GEOMORPHOLOGY				
Graphics	**Expert**	**C1**	**C2**	**C3**
2.1Terrain profile	Shows recognizable features	Get an idea of the area	Assess the domain extension	Assess the domain extension
2.2 Peacks and ridges		Estimate if go up in altitude	Go up in altitude	Go up in altitude
			Estimate snow quality	Estimate snow quality
			Locate, situate yourself	Locate, situate yourself
2.3 Slopes (stiff, craggy)	Render regional morphology	Estimate tilt	Assess tilt and risks	Assess tilt and risks
2.4 Corridors			Estimate dimensions	Estimate dimensions
2.5 Hollows, combes			Estimate the flat areas terrain	Estimate the flat areas terrain
2.6 Rocks, cliffs	Structuring the relief		Estimate possible crossings	Estimate possible crossings
2.7 Vegetation (fir trees)	Gives the direction of the slope		Characterize an alitude	Characterize an alitude
				Indicate uncrowded area
2.8 Snow and ice (hues variance)	Indicate glaciers in contrast with the snowy areas of low altitudes			Indicate glaciers contrast with the snowy areas of low altitudes

Table 5. Information from geomorphic graphics

3. TRACING				
Graphics	**Expert**	**C1**	**C2**	**C3**
3.1 Colored ski runs	Indicate difficulty level	Indicate difficulty level	Indicate difficulty level	Indicate difficulty level
3.2 Ski runs geometry	Show curving traces		Understand network organisation	Understand network organisation
			Estimate dimensions	Estimate dimensions
3.3 « Green » areas		Indicate quality level	Indicate quality level	
3.4 Ski lift	Give realistic proportions and distances	Look for directions and connections	Look for directions and connections	Look for directions and connections

Table 6. Information from tracing graphics

4. STRUCTURES				
Graphics	**Expert**	**C1**	**C2**	**C3**
4.1 Pictograms	Indicate a service, an alert	Indicate a service, an alert	Indicate a service, an alert	Indicate a service, an alert
4.2 Buildings	Give the main organization of the ski resort		Locate, situate yourself	Locate, situate yourself
4.3 Roads	Give the main directions of the plan			

Table 7. Information from symbols and structural graphics

4. NOMENCLATURES				
Graphics	**Expert**	**C1**	**C2**	**C3**
5.1 Names of the ski runs	Identification of the runs	Identification of the runs (when skiing)	Identification of the runs (when skiing)	Identification of the runs (when skiing)
5.2 Names of the ski lift	Identification of the ski lift	Identification of the ski lift (when skiing)	Identification of the ski lift (when skiing)	Identification of the ski lift (when skiing)
5.3 Elevation values		Evaluate heigh	Evaluate heigh	Evaluate heigh
5.4 Toponyms	(Provide geographical points of reference for) Location	Location	Location	Location

Table 8. Written information

The tables allow locating the information common to the expert and to the skiers, and among level groups.
The most shared information seems to be those related to the tracks, the structures and the designations. This information is also distributed equally among the three groups, while the information on the geography and geomorphology appear to be corollaries, especially for novices (C1). The geomorphic information are richer and more accurate to as the skiing level increases, terrain reconnaissance becomes predominant for advanced skiers C3. Individual information collected by skiers may be related to the purpose of use. According to the basic user's procedure (ref. Table 3) and for all the skiing levels, actions E11 and E12 require essentially geographic and network information. Actions E21 and E22 require geomorphic, network, and structural information, actions E23 and E24 structural information (pictograms). Action E31 requires structural information[2]. Decision making and conducting actions in a discovery approach of a ski area, is not without hesitancy among skiers. We intend in this regard to focus on the difficulties experienced by skiers during information processing. These difficulties in reading and interpreting ski map raise the question of compatibility between mental representations of the artist and those of users. The following section presents a focus on difficulties' typology.

[2] Proportion obtained on the average of occurrence of graphics categories in the verbal data segments.

3.3.1 Main difficulties in information processing

Difficulties may be manifested by misunderstanding, uncertainty, inconsistency, lack of details, and illegibility about representations. We listed them by category and graphics objects concerned. They are illustrated with excerpts of user verbatim (Table 9 to Table 13).

1. GEOGRAPHY		
Graphics	**Intermediate/C2** ***Verbatim***	**Advanced/C3** ***Verbatim***
1.2 Orientation and sunlight exposure (shadow contrast)	*"This is something that is not always easy to see on these maps. I do not know if the North is up, but on a ski map I have no idea"*	*"What is the majority of the exposure? I do not know how it is exposed ... "*
	"Here I concretely do not know where I am"	*"Depending on the orientation of the sun to enjoy the morning, I deduce it a little with the slopes, I will say that the North is there ... But I have no indication"*

Table 9. Sample of verbatim expressing difficulties about geographic representations

2. GEOMORPHOLOGY			
Graphics	**Novice/C1** ***Verbatim***	**Intermediate/C2** ***Verbatim***	**Advanced/C3** ***Verbatim***
2.2 Peacks and ridges			*"Up it is complicated to identify the relief, there is very flat and the plan does not allow to understand well"*
2.3 Slopes (stiff, craggy)		*"And there the vertical drop allows me to go there? I'm not quite sure. I have a doubt. Here I do not see well enough".*	*"We can maybe get out a little (free-ride) but I do not know, should be there."*
2.5 Hollows, combes	*"It sounds pretty steep; in fact it is a hollow. I feel that this is quite steep, yet there are only blue runs..."*	*« It was a shadow where we imagine a hollow so it's a little weird."*	*"Here you do not know if it passes. And then one feels a valley, but it is badly drawn.*
2.6 Rocks, cliffs		*"There I do not know what it looks like"*	*"It would be good to have the contour and IGN map (25millième) you would see right off the rocky ridge."*

Table 10. Sample of verbatim expressing difficulties about geomorphic representations

3. TRACING			
Graphics	**Novice/C1** ***Verbatim***	**Intermediate/C2** ***Verbatim***	**Advanced/C3** ***Verbatim***
3.1 Colored ski runs	*"Green and blue, sometimes they intertwine and there we lose the thread. They are too stuck together; it seems difficult to see exactly which track to take. "*	*"What it seems strange is that if it's a green it cannot be so steep"*	*"This is a blue run. But then I do not know if it goes down or it rises."*
3.2 Ski runs geometry	*"I'll take the blue called Col, and then ... But I am trying to get up there?"*	*"It is a bit small and it is not easy to see the connections of the tracks. When you are stuck you cannot use the map you if you do not know where to turn".*	*"Here I would like to know anyway ..."*
3.3 « Green » areas	*"The green spots I am somewhat lost, especially as it is written very small"*		
3.4 Ski lift		*"The second section is not super clear if it stops there or not, I still have trouble reading where the tracks stop"*	*"It's always the difficult part on a ski map, to understand whether in fact it connects, if it goes up or goes down..."*

Table 11. Sample of verbatim expressing difficulties about tracing representations

4. STRUCTURES		
Graphics	**Intermediate/C2** ***Verbatim***	**Advanced/C3** ***Verbatim***
4.1 Pictograms	*"If there was a bar or restaurant in altitude it can also be very interesting. But this is not very clear"*	*"The contrast with the green, I do not see ... Green is seen very badly, probably a color contrast problem, as it is on a shaded area"*
4.2 Buildings	*"Hence the fact that all the cottages are designed disturb my reading, I cannot too much to see, so yes it made me annoyed"*	*"I do not understand if it's far away..."*

Table 12. Sample of verbatim expressing difficulties about structural representations

5. NOMENCLATURES			
Graphics	**Novice/C1** ***Verbatim***	**Intermediate/C2** ***Verbatim***	**Advanced/C3** ***Verbatim***
5.1 Names of the ski runs (and ski lift)	*"The green slopes takes a bit to find them anyway, they are not easy to read"*	*"Sometimes we are at a crossroads, and we do not see the name of all tracks. I'd rather have areas where I can zoom"*	*"The problem of this map is that it is difficult to read names"*

Table 13. Sample of verbatim expressing difficulties about reading of proper nouns

The difficulties were quantified according to the frequency of appearance in the discourse of the subjects (skiers). From a total of 55 expressions of difficulties identified in the utterances of the corpus, 30.9% are related to representations of geomorphology, 27.3% of tracing, 18.2% of structure, 16.4% of geography and 7.3% of nomenclature.

Deeper analyses from reading of the Alpes d'Huez ski trails map about the type of difficulty related to the geomorphic and tracing representations showed the following percentages: 100% of participants reveal uncertainty [*"I'm not sure that…"]*; 44.4% of participants reveal a visibility problem [*"Not easy to see or to read...*], 33.3% of participants reveal a problem of understanding [*"I don't know..."*] and 22.2% of participants reveal an inconsistency of the ski map [*"It's a little weird..."]*.

4. DISCUSSION AND PERSPECTIVES

The experiment we conducted is exploratory and provided qualitative results. These results correspond to the formalization of rules in use of ski plans by skiers. The usage rules are governed by the need to perform a task or making decisions and by the user's ability to process representations (external and internal).

At the same time, rules for making a ski plan, characterized by conceptual tasks and technical tasks, have been identified. The creation rules are governed by numerous parameters (such as suitability for the marketing application, knowledge of the terrain, etc. ...) and they lead to the representation (external) of graphic objects constituting the mountain environment.

Among the tasks and actions that regulate the creation of the ski map, particular interest is given to terrain *invention*. This is the main conceptual task, but it is difficult to capture: it is a deformation strategy, a snapshot, a spatial decision of the artist at a specific time in a specific situation. It is reflected into technical tasks through actions of rotation, exaggeration, reduction and replication of shapes, enlargement, etc… and the resulting graphical objects are visible in the 2D scene, while they are invisible in the real scene.

It is not clear how the invention impacts user spatial reasoning. Does the invention of the territory facilitate or hinder the completion of the users' task? Our preliminary results show that difficulties in interpretation (misunderstanding, uncertainty) seem to be more evident in locations where there has been significant invention. The difficulties are especially related to the representation of the exposition orientation, the geomorphology and the connections of ski runs and ski lifts. The artist says that "if we chose definitively to direct (the ski plan) East-West ... we have to find tricks to create typical shadows that people are used to seeing". However, the results show that among skiers sensitive to the orientation of the slopes for reasons of snow quality, (C2 and C3 levels) there is a misunderstanding of the orientation.

A significant example is the representation of the area of Auris en Oisans, situated on the Alpes d'Huez ski map. The artist says that "if I made a servile representation, I would have to turn this mountain, so we have a whole section there, which will fill the view with something that is not interesting. So I prefer to turn the village of Auris, so that all tracks are on the profile nearby Alpes d'Huez. So I prefer not to take care of the real topography but mostly take care of representation as I want to give".

The consequences of this action are that both villages are close together and visible, the distribution of ski lifts and ski runs is concentrated only on the slope overlooking Alpes d'Huez and some ski lifts' geometry do not seem to follow the landscape. (i.e.: Auris Express chairlift). Indeed, the results show effects of misunderstanding, inconsistencies and uncertainties about the up and down directions of the tracks and intersections, located exactly in the area of Auris en Oisans. Figure 5 shows the real location of the villages of Auris en Oisans and Alpes d'Huez from Google maps imagery 2015. Figure 6 show a zoom on the location of the two villages in the ski map from Atelier Novat.

Figure 5. Real position of Auris en Oisans and Alpes d'Huez from Google maps images©2015

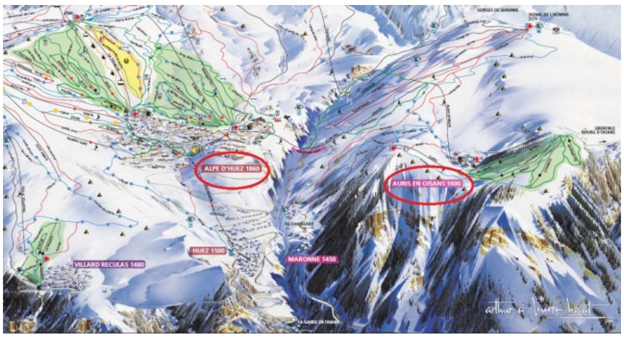

Figure 6. Deformed position of Auris en Oisans and Alpes d'Huez from Atelier Novat.

Following our experience, analysis of the invention shows that it can generate, in the skier, inhibitions for the realization of a task. In a computerized process perspective, where invention should be transferred to an expert system, we need to have a better control of the features that regulate this working rule. Therefore, further analysis including expert's tacit knowledge analysis methods, are needed (Cianciolo *et al.,* 2006).

These preliminary results provided an inventory of expert and users presentations and allow refining future research questions. A quantitative approach will be necessary to measure the use of graphic objects. It will be implemented through an eye-tracking study of observed graphics on ski maps, which will corroborate (or not) the semantic taxonomy and through a large-scale online questionnaire.

In a 3D software development outlook, the contribution of our results is in terms of advice, resulting from the difficulties and user feedback. For instance: option to locate, to zoom into an area, to get more information about geographical attributes of an object, to make queries for relevant information.

In a socio-historical perspective, these results help to enhance the discussion on the challenges of renewal of (geographical) information representation for an environment with strong territorial features, such as winter sports resorts. Dealing with the diversification of needs and requirements of users, the mountain operators, supported by the work of scientific research, should reflect on the relevance and effectiveness of the message they want to convey to the tourist.
Despite the information cloud that technology allows to supply (flow information in real time, weather conditions, etc…), mountain's operators still wish that ski trails map mostly address a message of vastness, beauty and dreams. In this respect, the aesthetic and emotional roles of panoramas need to be evaluated to be included in the information.

5. CONCLUSION

Ski map is an artifact, which characteristics can be analyzed from two points of view: its creation and use.
This artifact can be considered a "hijacked artifact" since it was born as a support to contemplation and became a support for decision making. This metamorphosis lasted for 40 years and formatted the reading of the mountain of generations of practitioners and tourists.
Aware of this heritage, the cognitive study presented in this article attempts to improve knowledge on artist-expert representations, those that are apprehended by the user-skiers and those that generate difficulties in interpretation, notably for the invention of the territory. It initiates our research on qualitative and quantitative recommendations which could be provided in order to ensure the adaptation of the panorama to the digital era.

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