AN EXPERIMENTAL APPROACH FOR STUDYING THE PERCEPTION AND MEMORISATION OF ANIMATED MAPS OF RISK EVENTS

CHESNEAU E.(1), VALORGE A.(1), CUNTY C.(2), TREMELO M.L.(3), MANDRAN N.(4)
(1) Université Lyon - UMR CNRS 5600 EVS - ISTHME, SAINT-ETIENNE, FRANCE ; (2) Université Lyon - UMR CNRS 5600 EVS, faculté GHHAT, BRON, FRANCE ; (3) UMR CNRS 5600 EVS, ENS Lyon, LYON, FRANCE ; (4) UMR CNRS 5217, LIG, GRENOBLE, FRANCE

1. INTRODUCTION

Since the 1990s and the digital era, maps have evolved significantly thanks to the appearance of new forms of mapping such as animated maps (which represent a phenomenon at different time periods and/or from different viewpoints), interactive maps (which give users the possibility to become actively involved) or multimedia maps (which connect up to other media such as sound, images, pictures, animation or videos). What contributions do these new forms of mapping bring to the cartographic portrayal of risk events? This is a very broad issue covering many aspects, which we propose to tackle in this paper by focusing on animated maps for representing temporal information on natural or technological risks.

A risk may be defined as '*the conjunction of a hazard (a disaster such as an avalanche or a flood, to which a probability of occurrence, an intensity and a spatial spreading may be associated) and various elements at risk (property, people, activities and functions), which are of a certain value (economic, cultural heritage, aesthetic, emotional, strategic, environmental) and a certain vulnerability (structural, physical or functional)*' [8]. When a risk occurs in a certain territory, it is called an event, which is composed of one or more exposed phenomena and elements of the territory [1].

A static map alone may be used to represent the spatio-temporal characteristics of risk events. However, users may find it difficult to read and understand such maps as they are often packed with too much information, thereby rendering the temporal component much less obvious (Fig. 1).

In order to increase the visibility of this temporal component, we can use a series of static maps in which each map is representative of a particular instant. Another possible solution would be to create an animated map in which the time of the event is represented by the animation time. According to [1], temporal animation allows us to express a change over time; it serves the purpose of explaining a process and revealing models or relationships that would otherwise be missed on a static map [7]. Furthermore, it creates a real sense of motion [11] thanks to the deduction of what the reader memorises while watching the animation. According to [7], the eye-brain mechanism captures images without recording them and, indeed, only records movements.

In this paper, we propose to study how users perceive and memorise spatio-temporal information about events shown in animated maps. We note in particular that the French cartographer Bertin formulated the hypothesis that '*motion provides an additional, dominant variable that uses up one's perceptive abilities, greatly restricting the attention that may be paid to the meaning of the other variables*' [2]. We wish to investigate, at different spatio-temporal reading levels, whether the spreading action of a phenomenon is indeed better perceived and memorised compared to other elements such as animated colour representations, static base maps or temporal legends.

This study corresponds to a first exploratory investigation [12] in which an experimental protocol was devised and a pilot test was conducted. Section 2 presents this protocol. Section 3 describes the results obtained from the pilot test and presents a review of the experiment. In Section 4, we propose some initial avenues of investigation for an ongoing research project, supported by Rhône-Alpes region, France ('PerçuRisk', 2010-2012).

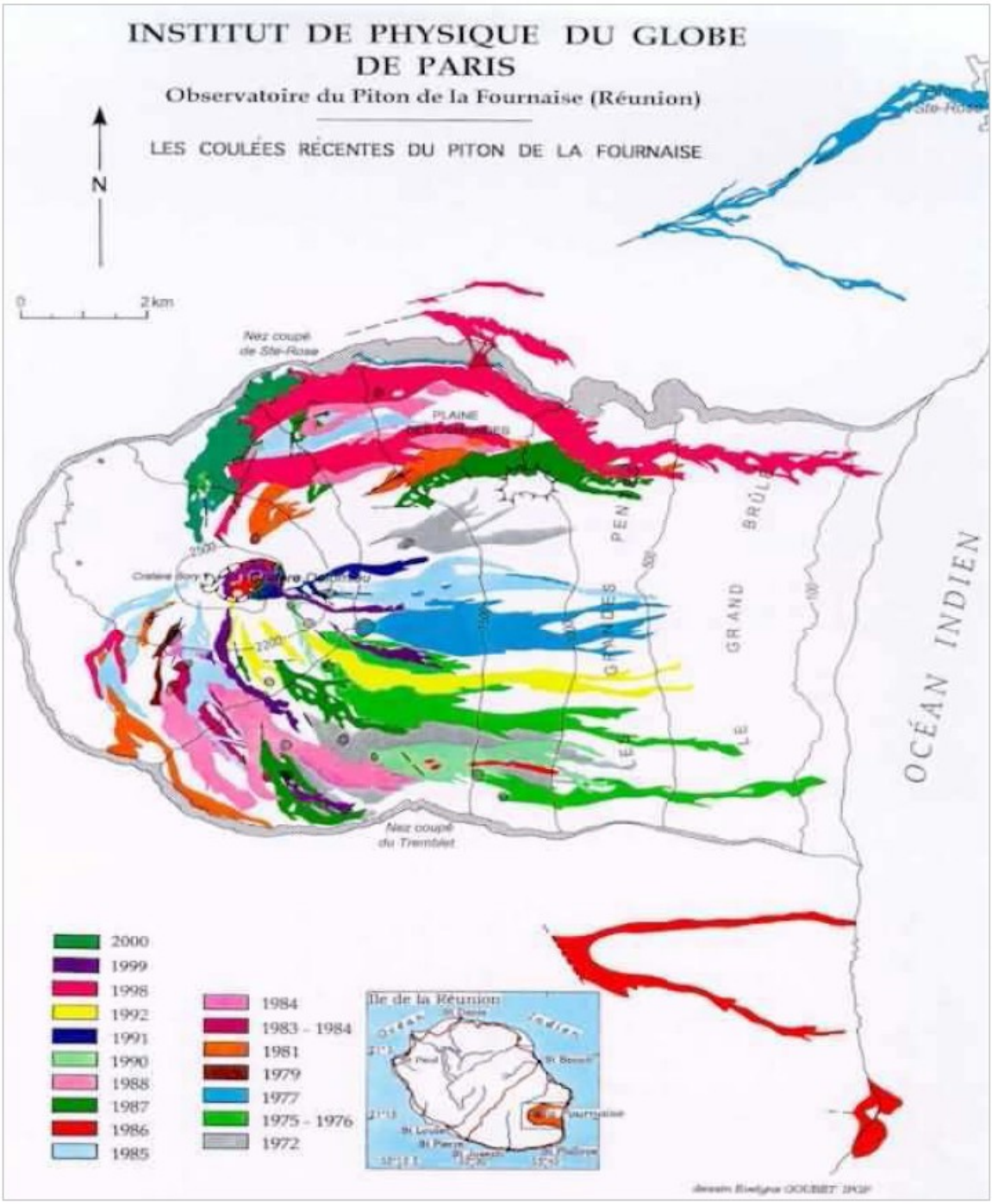


Fig. 1. Lava flow on the Piton de la Fournaise between 1972 and 2000 (© Arnaud 2009, p. 186)

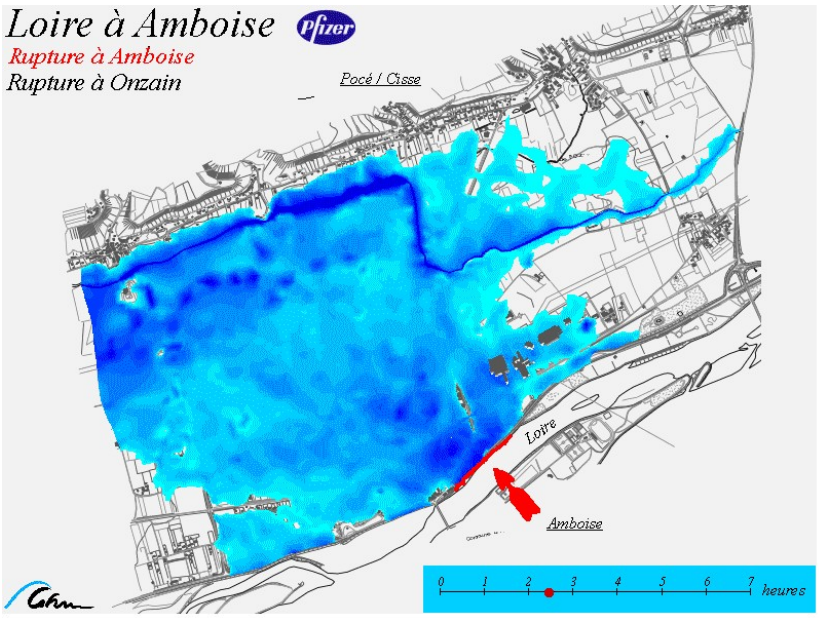
2. TEST PROTOCOL

2.1. Choice of assumptions, maps and participants

The aim of this work is to analyse the assumption whereby movements that translate variations in the spatial spreading of a phenomenon obscure the perception and memorisation of other information (varying colour intensity representing the relative intensities of the phenomenon, base map, temporal legend). We would especially like to study how changing colours in an animation are perceived and memorised compared with the spreading action of a phenomenon. To do so, we decided to work on three existing animated maps that depict changing phenomena by means of intensity variations represented by different colour choices. These maps are intended for the general public for communication purposes (Fig. 2).

As part of this exploratory investigation, we chose to carry out a pilot test to validate the experimental protocol that was established. This was achieved by questioning a limited number of people (six

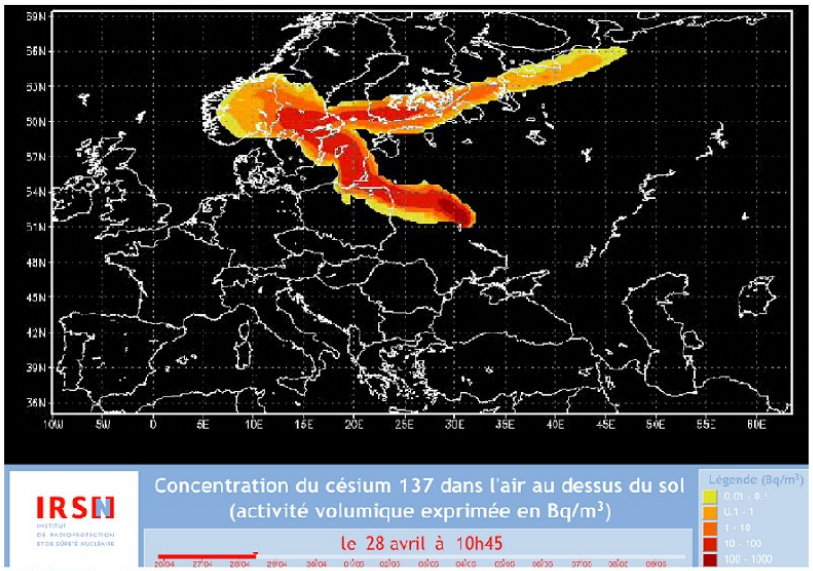
participants). These people came from a variety of backgrounds: geographers who used maps on a daily basis, non-geographers who were familiar with using maps and people who were unfamiliar with using maps; therefore, there may have been differences in their knowledge of maps. This pilot test allowed us to obtain some first results on our starting assumption, and most of all to identify any difficulties presented by the experimental protocol, which could then be taken into account in the 'PerçuRisk' project. The observations carried out will subsequently be of help in proposing certain graphics recommendations for creating animated maps that are more easily perceived and memorised by users.



M1: Floods in the towns of Amboise and Onzain resulting from dyke failures

© CETMEF (Maritime and River Technical Research Centre/Centre d'Études Techniques Maritimes et Fluviales)

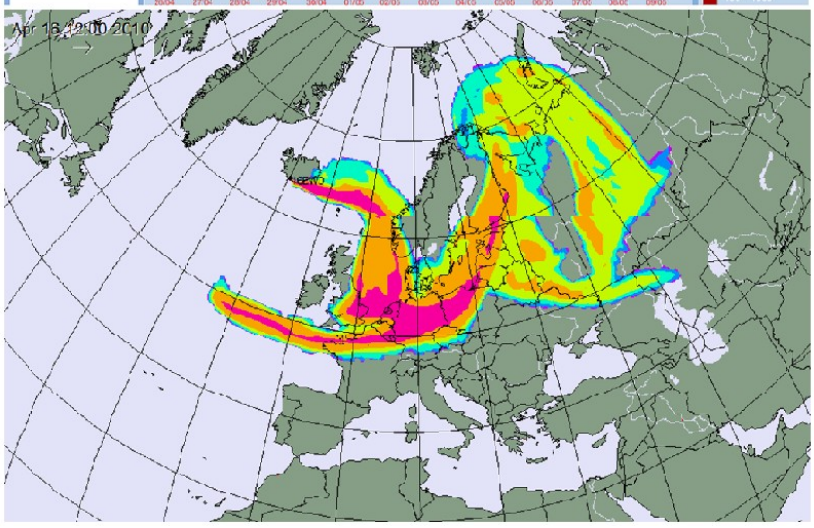
M1 represents the spreading of flood waters in the Loire arising from two dyke failures at Amboise and Onzain, with variations in water depth being represented by the varying brightness of blue. The dykes are symbolised by red and orange arrows that start to blink once failure occurs. The base map, which is in black and white, is a cadastral one. The map contains a title and a temporal legend represented by a progress bar indicating the number of hours that have elapsed since the onset of the first dyke failure.



M2: Spread of the Chernobyl cloud in April 1986

© IRSN-France
http://www.irsn.fr/FR/popup/Pages/tchernobyl_animation_nuage2.aspx, viewed on 28/01/11

M2 shows the progression of the Chernobyl cloud and the changes in radiation levels represented using colours (colour gradient from yellow to red) between April 28 and 30, 1986. The base map shows the boundaries of countries in the European region against a black background. The map contains a title and a temporal legend represented by a progress bar indicating the number of days. A map legend is also present.



M3: Progression of the volcanic ash cloud of Eyjafjallajökull in April 2010

© http://i.imgur.com/flMMU.gif, viewed on 28/01/11

M3 shows the progression of the ash cloud of Iceland's Eyjafjallajökull volcano between April 14 and 19, 2010, as well as the various ash concentrations (colour gradient from blue to pink). The base map shows European countries in grey. The map contains a temporal legend in the form of a digital display of the number of hours.

Fig. 2. Animated maps selected for the test

2.2. Three-step test protocol: questioning, narration, discussion

Our protocol is based on several experiments led by cartographers ([6], [10], [9]), as well as the expertise of some cognitive science researchers.
An animation grid for specifying the steps to be taken during the test, their order and duration was created: upon reception of the participants (step 1), the latter are introduced to the objectives and the main sections of the test by means of an animation guide (step 2). Next, instructions are given and the maps are viewed one after another (step 3). A paper questionnaire is then distributed to the participants, who proceed to answer the questions (step 4).
The aim of the questionnaire is to analyse what participants remember after having viewed the maps, and more specifically the spatial spreading of phenomena and their intensity variation at several spatio-temporal reading levels [6]. Table 1 presents the four levels that were selected. For each level, two questions were asked: one on the spatial spreading of the phenomenon and the other on colour intensities.

Reading level	Explanations	Examples
First level (Global Global)	Overall questions in space (entire mapped area) and in time (entire animation)	Spreading phenomenon: '*Sketch the change in position of the phenomenon throughout the animation*' Colour intensities: '*Sketch the change in position of the maximum intensity of the phenomenon (of a particular colour) throughout the animation*'
Second level (Intermediate Local)	Questions on a part of the mapped area at a given instant in time	Spreading phenomenon: '*At a given instant t, what areas did the phenomenon pass through?*' Colour intensities: '*At a given instant t, what areas did the maximum intensity of the phenomenon (particular colour) pass through?*'.
Third level (Local Intermediate)	Questions on a particular geographical site on the map within a given time period	Spreading phenomenon: '*Did the phenomenon pass through this site between t1 and t2?*' Colour intensities: '*Did the maximum intensity of the phenomenon (particular colour) pass through this site between t1 and t2?*'.
Fourth level (Local Local)	Local questions in space (particular site) and in time (particular instant)	Spreading phenomenon: '*At a given instant t, did the phenomenon pass through this site?*' Colour intensities: '*At a given instant t, did the maximum intensity of the phenomenon (particular colour) pass through this site?*'

Table 1. Reading levels for the questionnaire

Thus, in this step, there are eight questions for each map (two per level: one on the spreading of the phenomenon and the other on colour intensities); how then may we prevent participants from feeling lost? We decided to ask questions according to reading level, rather than on a map-to-map basis: for a given level, each map is viewed just once and is followed by two associated questions on spreading and colour intensity. The answers are timed in order to elicit the most spontaneous response possible and therefore activate the participants' working memory.
After the questionnaires are collected, a two-step debriefing session is held. First, participants are shown the map once again and are invited to describe what they see during the viewing session (*'describe what you see')*. This narration (step 5) allows us to assess what participants perceive while the animation is in progress: do they describe the spreading action of the phenomenon or the movement of the colours?
A discussion (step 6) then follows, during which the participants' comments are recorded in an audio format. This allows us to keep an exact record of what is said, and subsequently analyse the latter with the greatest possible accuracy. Thanks to this semi-structured discussion, participants can express what they did or did not understand or appreciate. Another aim of this discussion is to provide further information with regard to our assumption on the dominance of the perception of movement over that of intensity variations.
At the end (step 7), the persons questioned are asked to provide details on their identity, especially in terms of their professional background and any knowledge relating to risk and cartography.

2.3. Response bias

The choices that were made for this test sometimes led to some bias in the answers. Some types of bias were predicted when the protocol was being established, while others were only identified after the pilot test was carried out:

- Participant interest in the map being viewed: attentiveness may vary according to whether the topic being addressed or the territory being mapped captures the participants' attention for personal reasons (past experience, personal interests, etc.). Thus, the perception and memorisation of the information represented may vary independently of the implemented map choices that form the basis of the test.
- Participant familiarity with maps: participants may become more and more used to the maps as they go from one reading level to the next. They may then notice elements that they did not see or remember the first few times. This type of bias, which was identified while the protocol was being set up, may be reduced by choosing to arrange the reading levels in such a way that users have to answer questions that require an overall reading of the map before answering more precise questions associated with a more local, detailed reading ([2], [3]).
- Participant familiarity with the types of questions asked at the same reading level: at a given level, participants may find it easier to answer questions on the third map than those pertaining to the first two maps because they are already more familiar with what they are asked. This sort of bias may be reduced thanks to step 3 of the test, in which the instructions mention the types of questions that participants should expect as well as some examples of these questions.
- Varying levels of difficulty in the questions asked for different maps at the same reading level: based on the results of the questionnaire, it appears that users find it easier to answer some questions on M1 than those pertaining to M2 and M3. This may be because of differences in the difficulty level. For example, with regard to the spreading action of the phenomenon at the 'Intermediate Local' level, for M1, we ask users if the selected polygon is flooded at a given instant, whereas for M2 and M3, we ask them to choose one of three samples showing the countries affected by the cloud at a given instant.
- Difficulty in interpreting response times: we started off by assuming that the response time was a direct reflection of the participants' ease in answering a question. However, in hindsight, it turns out that some questions may require a longer response time than others without necessarily being indicative of participant hesitation. For example, it takes longer to sketch the trajectory of a phenomenon than to answer a 'yes/no/don't know' type of question. In addition, the questions themselves may require different lengths of time to be read and understood.
- Too many types of maps, of which not all parameters are well controlled: in order to test the perception and memorisation of the spreading action of phenomena compared with that of colour intensity, we made the deliberate choice to use maps with many different legends, base maps, scales and settings. However, we subsequently noticed that this complicated the analysis even further because of the presence of too many uncontrolled parameters. This sometimes made it difficult to explain a particular result.

3. PILOT TEST AND ANALYSIS OF RESULTS

A pilot test was conducted among six participants: three geographers (two secondary school students and a secondary school history/geography teacher), an expert in hydraulics who was familiar with using maps in his work, and two novices in the fields of cartography and risk. Each participant had to sit an individual test, on a one-to-one basis with a facilitator.

To ensure a homogeneous approach, the two facilitators involved in this experiment conducted the first two tests together (with one conducting the test while the other observed); each facilitator then conducted two tests on his or her own. The conditions relating to lighting, place and time of day were not the same, which is not a problem in this exploratory step of the experiment. However, they must be homogenised when the test is generalised in future.

3.1. Analysis of responses for each spatio-temporal reading level

The answers to the questionnaires are presented in Fig. 3: the graph on the left shows the number of correct answers on the spreading of the phenomenon, and that on the right shows the number of correct answers on colour intensity.

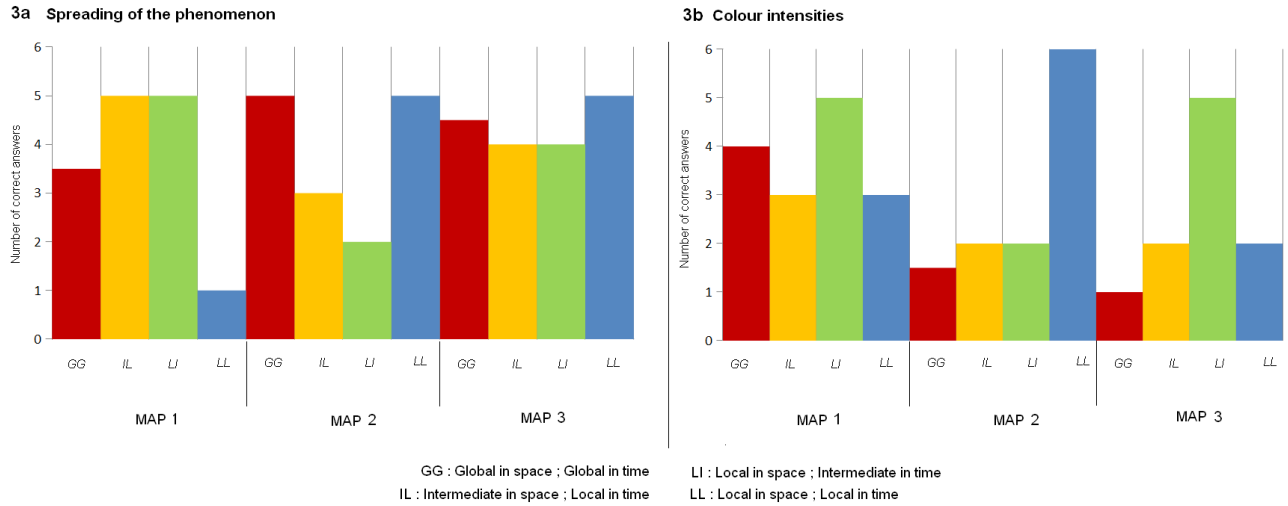


Fig. 3. Number of correct answers to questions relating to the spreading of the phenomenon (3a) and colour intensities (3b)

As there were only a small number of participants, we are unable to draw statistically significant conclusions. We may nonetheless observe a strong trend: it appears to be easier to perceive and memorise the spreading of a phenomenon than the intensity variations represented by colours, especially at the 'Overall Overall' and 'Intermediate Local' levels.

Furthermore, there are strong differences between the maps in terms of the number of correct answers, according to reading level. For example, with regard to the spreading action at the 'Local Local' level, there are few correct answers for M1, whereas there are many correct answers for the other two maps. As for the spreading action and the movement of colour intensities at the 'Local Intermediate' level, the number of correct answers is low for M2 compared to those for the other two maps. At this stage, it is hard to determine the root of these differences: does it have to do with the difficulty level of the information to be spotted, which may vary from one map to another at the same reading level, or does it concern the quality of the cartographic portrayal (non-intuitive colour progression in M3 that could influence the number of incorrect answers)?

These variations have prompted us to conduct all future tests using a single map (that we will create on our own) in the 'PerçuRisk' project, in order to ensure good control over the parameters being tested.

3.2. Analysis of narratives and discussions

The aim of studying the narratives is to identify the topics that are or are not described, from the spreading action of the phenomenon to the movement of colour intensities. The analysis of the discussions will allow us to identify the factors that facilitate the memorisation of these two topics.

What topics are perceived and how are they described? (analysis of narratives)

The phenomenon that is mapped is described in terms of its starting point, the direction that it takes while spreading, and the areas where it spreads and stabilises. 'The flood originates from the south, southeast, from the barrier that has just collapsed. It spreads towards the northwest until the river that is in place' (M1). The participant mentions mainly the areas that are most affected by the phenomenon, in other words those that are represented by the greatest intensities: 'the highest densities of ashes move mainly towards France and the United Kingdom [...] highly concentrated portion moving over the sea, gradually returns westward' (M3). Areas that are less or not at all affected are also spotted: 'The cloud starts to reach Central Europe, with Germany and France being affected. England is slightly spared. [...] The eastern region is greatly affected at the moment; Russia is almost completely covered by the cloud, which still hasn't reached Spain' (M3).

What factors facilitate the memorisation of topics? (analysis of discussions)

The use of motion helps in memorising the spreading of a phenomenon: 'The first time, we see that there is movement, we see the blue spreading, and that's it' (M1), and even more so if the spatial variation over time is predictable: '[For M1], easier to remember as phenomenon is a bit more predictable... The overall phenomenon can be seen relatively clearly. With the other maps, there are winds that sometimes cause abrupt changes in the cloud direction, so it's harder to remember the evolution'. However, the participant may have difficulty memorising the spreading action if it varies significantly over time; in this case, the brain only recalls a few spatial positions at precise instants: 'When you look at the animation just once, you tend to only concentrate on one part of it. There is no time to look at all the areas at once and there are movements that

you don't notice: the image appears for longer afterwards and you guess that maybe things took place in a certain way during this time, but they could in fact have happened in another way' (M2).
Participants spot colour intensities thanks to their movement, especially if the latter follows the spreading action closely: 'you're attracted to the blue that moves' (M1). With M2, participants find it difficult to remember how the red portion (highest concentration of cesium) spreads over time because its movement is different from that of the overall spreading of the phenomenon: 'At the beginning, the most toxic part of the cloud remains centered around Chernobyl. There is a small part of the cloud that does not go very far, somewhere towards the Baltic sea. The part that subsequently moves towards the north and north-east remains less dense. Apart from this, I can't say a lot more about the dark red bit' (M2). In any case, it is generally more difficult to memorise colour intensities than spreading actions: 'I was looking mostly at the spreading, I didn't really notice the colours that well' (M1 to M3), and all the more so with complicated movements: 'I can mostly see the movement and the dispersion of the cloud. But it's very complicated. The complexity of the cloud makes you notice the movement first; colour comes afterwards and is not so easy' (M3). A simple spreading action would therefore allow viewers to better remember the intensities: 'There is a bit more time to talk about the concentration because there is nothing much going on' (M3).
The colour intensities that are best memorised are the extreme ones (light, dark), especially the strongest colours: 'As for colours, first there are light colours, then dark ones' (M1), 'During the first reading, you tend to notice the shape of the cloud and the difference in intensity between the east and the west' (M3), 'I see the cloud movement and the dark red colour' (M2). We can nonetheless improve the memorisation of intensities by following certain recommendations based on the participants' comments (Table 2):

Recommendations	Participants' comments
Few colour intensities	*'The colours are simple, it seems like there are four colours'* (M1). However, for M3: *'I notice the pink area most of all, it stands out well. It's harder with the others, there might be too many colours that are too different from one another.'*
Good distinction between intensities	*'The dark red colour is quite simple, I find it harder with the others. You can't see them well, I think they're not different enough, there might be too many of them'* (M2). '[The colours weren't sufficiently distinguishable?] *Yes, there wasn't enough difference in the shades.'* (M1).
Logical intensities that facilitate comprehension and therefore memorisation :	*'The maximum intensity in red is easily understood, then it spreads while losing a little intensity and moves towards the east in yellow, which is lighter, with the darker bit being concentrated a little around the west, I think. It's noticeable. It's quite clear'* (M2).
- It seems that the choice of a single colour for representing different intensities facilitates memorisation	'[It's mainly the movement of the object that you notice.] *Yes, it's harder with the colours, except for the map on the flood* [M1]'.
- Conversely, illogical colour choices such as those in map M3 complicate matters	*'There seems to be colours everywhere and it's hard. On the whole, I noticed the colour intensities because they were easily visible, but I don't know about the levels indicated and all the rest'.*
- This difficulty in memorising illogical intensities can be reduced by making the spatial organisation of the colours correspond to a gradient	*'And where there is some intensity or not: I didn't see the legend but I suppose that it's red, pink, orange, green, blue. Actually, it's the layout in the map that determines whether you can understand it or not; other than that, I don't know whether there is a difference between the green and the blue in terms of intensity itself.'* (M3).
Colours with cultural codes that are familiar to the participant	*'Blue represents water, you can tell the depth of the water by looking at the colours'* (M1). *'I find the dark red colour interesting because there is a dangerous quality to it. I think the high-radiation zone is interesting to look at'* (M2).

Table 2. Certain recommendations to improve the memorisation of intensities

The last recommendation mentioned in Table 2 also highlights the fact that the amount of effort that participants put in to memorise information depends on their interest in the topic: the more a participant finds a topic motivating, the more he or she will try to remember the information involved.
In spite of these recommendations, it seems that participants only have an overall impression of the movement of intensities: 'You get an overall impression, but apart from that, it's hard to remember which colour was on which country' (M2).

3.3. Review of experiment

The following are some reflections that we made based on the comments made by the participants as well as our own experience:

- The participants had great difficulty in answering the questions. Indeed, each map contained a lot of information, which made it hard to perceive and memorise everything at the same time.

Furthermore, the questions that were asked required participants to pay close attention to many different topics: the spreading action of a phenomenon, colour intensities, time, base maps, etc. To overcome this problem, one participant suggested being allowed to view the animation along with the question several times. However, even when the animation was displayed several times, one recurring problem remained: it was still difficult to look at the map and the associated dates simultaneously. Time, i.e. the correlation between an instant in the animation and that in calendar time, is the parameter that is most often unnoticed and forgotten. This therefore makes it difficult to answer questions such as 'At instant t, what happened at the site X on the map?', and all the more so when the site in question covers just a small area.

- Another issue concerns the familiarity with the maps: when participants view a map several times, they might notice new elements that they previously failed to spot during the first viewing session. If this is the case, how can we test the information memorised at each reading level equally, and in what order should the questions be arranged to reduce this type of bias?
- Advance knowledge of the types of questions and their level of detail would also improve the ease of response. Indeed, it would allow participants to concentrate on the specific aspects of the animation that they will be asked about. As such, one participant suggested having even more precise instructions at the beginning of the test to be able to assimilate the meaning of the questions more easily.
- The maps tested seem too diverse for an easy and relevant interpretation of the results of the questionnaire. In future, we should create our own map, in which only a single element will be made to vary at any one time, in order to control the parameters that are truly being tested.
- Having participants who possess varying degrees of knowledge about cartography is an additional factor that contributes to differences in the perception and memorisation of information in an animated map. We should focus on one user profile alone (e.g. geography students, risk management professionals, etc.) to ensure better control of the experiment.
- The level of interest in the subject of the map or the space being represented can also influence the quality of the answers, or at the very least the participant's level of concentration while the map is being viewed.

4. PERSPECTIVES FOR THE "PERÇURISK" PROJECT

In this paper, we have only presented the first phase of a test protocol. A second phase on the factors influencing the appreciation of an animated map has also been carried out, in which it was assumed that a map is better appreciated and understood if it is perceived as being aesthetic, innovative, easy to use, clear, relatively simple in terms of the information being represented and of particular interest to the reader.

The first phase of the test will serve as a starting point for the 'PerçuRisk' project, supported by Rhône-Alpes region, France. The objective is to provide recommendations for a more relevant cartographic portrayal of spatio-temporal data relating to risk events (especially their temporal aspects such as instants, duration, order, etc.). We will create our own animated maps, which will be aimed at an audience with little or no knowledge of geography for communication purposes. We will then test them on participants to determine how the spatio-temporal information is viewed.

The present exploratory investigation has enabled us to identify certain interesting aspects that should be taken into account in the future project:

- First, the initial results obtained here must be developed further for more detailed analyses and more complete recommendations.
- One very important aspect that came up with this test concerns problems in perceiving and memorising temporal elements: indeed, among the participants' comments, the temporal legend is not described at all, and during the discussions, participants pointed out the difficulty in correlating the animation time with calendar time. We should therefore focus on the representation of time in our maps.
- Furthermore, it seems that base maps influence the level of perception and memorisation of information: a base map that is rather general, simple, allows one to identify the main features, is suited to the representation of the phenomenon in question (e.g. use of relief for floods) and of a known type (e.g. standard topographic base) appears to be more suitable. It would be interesting to test different types of base maps to determine if there are any differences in the way in which the information represented is seen by participants.

- The speed of the animation is also an important contributing factor to the relative ease of perceiving and memorising information.
- In phase 2 of the protocol, we discovered that it would be relevant to test several other factors, namely the role of interactivity and multimedia effects in an animated map, or the incorporation of a reading aid.

For the 'PerçuRisk' project, we propose to build an experimental map in which we will choose the topics to be varied: colour intensities, representation of time in the legend, base maps, interactivity, map reading aid. Few elements should be made to vary at any one time to make it easier to explain the differences in the results obtained.

In addition, we should specify what we wish to test and which measurement tools to use:

- What the eyes of participants look at while a map is being viewed? In this case, we will use an eye movement data collection method ([4], [5]) to obtain data on the map elements that participants do or do not look at or spot.
- What participants perceive while viewing a map? Narration enables the collection of data on the elements described by participants.
- What participants understand from the information presented in a map? In this case, we wish to find out if participants can correctly answer questions that are asked before a map is viewed.
- What participants memorise from the information presented in a map? In this case, we want to determine what information participants remember from a map that they have just viewed. Therefore, we could ask them questions on specific elements of the map to find out if they have memorised them.

Finally, while the test protocol is being set up, we should make sure that the reflections made in the review of the experiment are taken into consideration (level of difficulty of the questions asked, familiarity with the maps and the questions, participants' interest in the topic or the territory being mapped).

REFERENCES

[1] Arnaud A., 2009, Valorisation de l'information dédiée aux événements naturels de territoires à risque. Une application sur la couronne grenobloise, PhD thesis in Geography, Université Joseph Fourier, Grenoble 1.

[2] Bertin J., 1967, Sémiologie graphique : Les diagrammes, les réseaux, les cartes, Éditions EHESS, Paris. 431 p.

[3] Cauvin C., Escobar F. & Serradj A., 2007, Cartographie thématique 2, des transformations incontournables, Hermès Science publications, 272 p.

[4] Fabrikant S., Goldsberry K., 2005, Thematic Relevance and Perceptual Salience of dynamic Geovisualization Displays. Proceedings 22nd ICA/ACI International Cartographic Conference, A Corunã, Spain, July 9-16.

[5] Garlandini S., Fabrikant S. I, 2009, Evaluating the effectiveness and efficiency of visual variables for geographic information visualization. Proceedings, Spatial Information Theory, 9th International Conference (COSIT) 2009, Aber Wrac'h, France, sept. 21-25.

[6] Koussoulakou A., Kraak M.J., 1992, Spatio-temporal maps and cartographic communication, The Cartographic Journal, Vol. 29.

[7] Kraak M-J., et Ormeling F-J., 1996, Cartography, visualisation of spatial data. Harlow: Longman 1996, 2nd ed. 1997, 222 p.

[8] Leone F., 2002, Implications territoriales et socio-économiques des menaces naturelles en Martinique. Annales de géographie, 627-628, sept-déc., 549-573.

[9] Midtbø T. & Larsen E., 2005, Map animations versus static maps – When is one of them better? Proceedings 22nd ICA/ACI International Cartographic Conference, Content 14 of the Joint ICA Commissions Seminar on Internet-based-Cartographic Teaching and Learning: Atlases, map use, and visual analytics. A Corunã, Spain, July 9-16.

[10] Olson J-M., Brewer C-A., 1997, An Evaluation of Color Sections to Accommodate Map Users with Color-Vision Impairments. Annals of The Association of American Geographers, 87 (1), 103-134.

[11] Ormeling F-J., 1995, Teaching Animated Cartography, in: Ormeling F-J., Köbben B-J., Perez R. (eds), Proceedings of the seminar on Teaching Animated Cartography, Madrid 1995, Actes International Cartographic Association 1996, 21-29.

[12] Valorge A., 2010, Perception visuelle de cartes animées dédiées aux risques naturels et technologiques : contribution pour des propositions sémiologiques, Mémoire de recherche Master 1 en géographie, université Jean Monnet de Saint-Étienne, 167 p.