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Mobile maps usage under time pressure

Master thesis (Geo 511) of Flavien Rouiller

Under the supervision of Prof. Dr. Sara I. Fabrikant

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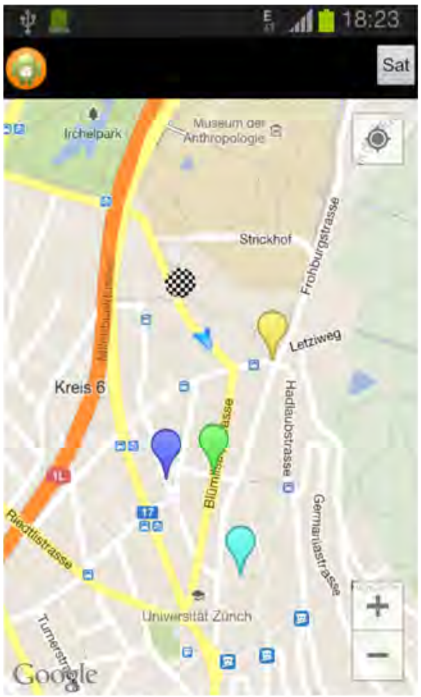

Screenshot of the application used in
the experiment of this thesis

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Abstract

This master thesis aims to compare the behaviour towards mobile maps of users under time pressure or not. Twenty-six participants took part in a between-subject field study based on a travelling salesman problem presented on a smartphone. GPS track, interactions, video and physiological data were recorded. The analysis led to the conclusions that time pressure is not accountable for the goodness of an itinerary but could lead to less major errors in its execution. Time pressure has an effect on the length of each glance at the map but not on the overall time spent looking at it. The interactions with the map are not statistically related to time pressure, but physiological data analysis shows that a relation might exist. Spatial ability was tested by a paper and pencil test and compared to the obtained variables. Participants with lower spatial ability had to look longer and more often at the map during the experiment to complete the task. This corresponds to one of two strategies of information gathering from the map and navigation possibly identified during the experiment and in the resulting data.

Keywords: Mobile maps, time pressure, navigation, skin conductance, spatial ability

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Personal Declaration

I hereby declare that the submitted thesis is the result of my own, independent, work.
All external sources are explicitly acknowledged in the thesis.

F. Rouiller

Table of Contents

Illustrations

Tables

Abbreviations

API – Application programming interface

GPS – Global Positionning System

SCL – Skin Conductance Level

SCR – Skin Conductance Response

TP – Time Pressure

UTC – Coordinated Universal Time

WiFi – Wireless Fidelity

YAH – You Are Here (type of map)

1 Introduction

From the first mobile phone to be considered "smart", the Nokia Communicator in 1996, it took sixteen years to reach the billion smartphone (nmwatson, 2012). According to the same source the second billion should be reached in 2015. It has become a standard to equip the devices with an inbuilt GPS and other possibilities of localization. The mobile devices have brought a new way of displaying geographical informations and maps are now a key feature offered by these phones. However, along with this new media, new problems appears that need a solution. Setlur et al. (2010) are identifying major issues: limited screen size, interaction mechanisms, processing power and memory space. It can be admitted that the last two issues proposed by Setlur et al. are likely to be reduced along with the technology progress and could soon be neglected for common tasks. But screen size and interaction processes are inherent of these devices: they must be small enough to fit in a pocket. If some new kind of devices could arise soon, for example Google glasses, and change again the rules of interactions and visualization, for now they are mostly futuristics and unavailable to the public.

Joly (1976) (as cited in Béguin and Pumain, 2003) defines the map as *"a simplified and conventional planar geometrical representation of the totality or a part of the earth surface, this in a relation of correct likeness called scale[1]."* This definition still holds for the case of mobile maps, even though the scale and the extent of the map are now variable and can be changed in a couple of finger movements.

A smartphone is a phone that not only proposes the classical remote communication functions, but provides more elaborate capacities. It is connected to the internet. Its screen is in colour and its resolution is high enough to display complex images. It is in some sense a pocket computer which is able to store and compute data through applications available on the Internet. It can locate itself using GPS, WiFi and phone antenna information. Smartphones are frequently used to display maps, known as mobile maps. Due to this mobility, the conditions under which the use of mobile maps occur are greatly variable. The information requested by the user is also varying. As a matter of fact, the paper maps used for driving or to visit a city were two different objects. They are now grouped, along with a large number of others maps, in one mobile map. Even in the common case when the user wants to go to a place and needs the help of a map to reach it, the conditions can be varying. First, the place to which the user wants to go can be of many sorts. From a touristic

1 In French: "La carte est une représentation géométrique plane simplifiée et conventionnelle de tout ou partie de la surface terrestre, et cela dans un rapport de similitude convenable qu'on appelle échelle."

highlight in a foreign city to an unknown shop in his or her home town. Secondly, the time available to reach this place is variable. If the time needed to reach the target is close or superior to the available time, and if being on time is important, then the user is under time pressure.

Mobile phones, in comparison with paper maps, are characterized by a small screen size. An intuitive way to compensate for the small size of the screen is to reduce the amount of information displayed on it. It might be risky as it moves the relevance analysis upstream from the user to the computer. A possible way for a computer to determine the relevance of search results, is to use the context of the query (Hong et al., 2009). The type of context the application could use is wide, ranging from driving/walking/running, hour of the day, personal preferences or, which is of interest in this study, time available to get to the target and time pressure felt by the user. It is easy to imagine how a phone could compare travel duration with current time and position of a user to determine the level of time pressure. Some more subtle input could be used, such as voice analysis (Marks, 2013) or the analysis of usage patterns (LiKamWa, 2012) to determine how the user is affected by this factor.

This work will attempt to discover what differs when the user of a mobile map is under time pressure. In this study, the time pressure will be induced by a time limitation and its effect on human physiology will be quantified by measuring the skin conductance level. The comparison of the data obtained from the captors of the smartphone and from the skin conductance level measurement tool will provide new informations about the behaviour and interactions directly related to important changes in stress levels.

By answering the working questions presented in Chapter 1.1, a better understanding of the change in behaviour induced by time pressure will be presented. This is a step towards designing efficient displays in a context of time limitation as well as a contribution to the understanding of the human-map interaction process.

1.1 Research questions

This work will aim to define how people react in their interactions with a mobile map as well as in their wayfinding strategy when they are put under time pressure. This work will be organized in order to answer the following research questions.

1.1.1 Does the itinerary choice change depending on time pressure?

This question is important to understand how the wayfinding and spatial decision making strategies are affected by time pressure. A few leads are available in order to propose an hypothesis of what could be the response. For example, Wilkening (2010) tested users with different types of maps as well as changing time pressure. The participants of his experiment had to choose an itinerary to reach one point on the map as fast as possible. He found that the route planning capacities decreased when time pressure was applied (i.e. that the itinerary chosen was not optimal).

The question will be answered by making a comparison of the quality of the itineraries between participants that were subject to time pressure with the one chosen by those who were not.

1.1.2 Does time pressure influence human-map interactions?

I want to discover if the time needed by the user to understand the information displayed on the map and take advantage of it varies whether the subject is submitted to time pressure or not. In a previous study it was found that the time involved in the reading of the documentation decreases when time pressure occurs (Maule et al., 2000). However, the experimental setting in this study is different from mine as it has no link to maps nor spatial tasks and I reckon my results could be different as well. One could intuitively answer in two opposite ways: the user will use the map shorter in order to save time, or the user will use the map longer to be sure of avoiding mistakes.

I think it is probable that a user who uses the map longer will also "play" with it more. Some literature indicates that the users under time pressure use less documentation than the others before making a decision (Maule et al., 2000), even though contradictory articles are also existing (Kerstholt and Willems, 1993). Different information sources can be understood in my case as different views of the map (e.g. scale, satellite/abstract map, moving the centre of the map). A part of this question will hence be answered by comparing the number of interactions.

The data needed to answer this question will be collected by using the inbuilt webcam of the phone to measure how long the user is facing the display (i.e. reading the map). The number and type of interactions the user is having with the smartphone will also be recorded.

1.2 Structure of this work

Following this introduction, the state of the art related to the subject will be presented in Chapter 2. This chapter will be divided into four sub-chapters, representing four distinct scientific fields that will all be used in this work. This chapter aims to present what has already been done in the field and on which basis this work is relying.

The method will be presented in Chapter 3. The programming of the mobile application and its requirement will be explained. The participants of the study are described. The tools used for this study will be presented. The design of the study is detailed next, presenting the variable that we plan to collect and how. The procedure of the experiment is then showed in such a form that it would be repeatable.

In the result section, the treatment of the raw data in order to obtain useful variables is explained first. The six following chapters (4.2, 4.3, 4.4, 4.5, 4.6 and 4.7) are focused on the statistical analysis of the variables regarding especially time pressure and spatial ability. Chapters 4.8 and 4.9 are focusing on the data collected by the physiological device. The Chapters 4.10 and 4.11 are observations about the map orientation and satellite view. The whole Chapter 4 is a central part of this work as it represents the raw and analysed outcomes of the data. The discussion and conclusion are largely based on this chapter.

The discussion (Chapter 5) will first answer the research questions under the light of the results presented in the previous chapter. Some other observations not directly related to the research questions, such as informations obtained from the spatial ability test, will be done next. The discussion closes with a critical self-analysis of this work.

The conclusion (Chapter 6) comments the outcomes of this work in a general manner, proposing some interpretation and highlighting the most important findings. This is followed by a sub-chapter about what could be done next to further investigate in the field of this thesis.

2 State of the art

The pooling of mobile maps and time pressure supported by physiological measurements is something that is new. Very few literature is available on the subject. This chapter will present closely related fields taken separately and propose some works that throw bridges between the fields.

First, the new and fast growing domain of mobile mapping will be reviewed. We will see that the design of maps must be rethought when using mobile device. We will also see how mobile maps simplify wayfinding activities. We will analyse the higher interactivity that is linked with those maps.

We will then present the notion of spatial ability and explain why it can be measured by the paper folding test. We will explain why it has been chosen to be a part of this study. We will see its relation with geography and compare it to similar tests.

We will concentrate on time pressure and its effect on human behaviour. We will see that this is an old theme that has been treated in a wide range of domains. Time pressure modifies the capacities of the subject to take decisions. We will take a look at a work that rely time pressure to cartography.

Finally, we will talk about the skin conductance level measured by the SmartBand device. We will understand what represents this measurement and see that it is used in several fields. We will also discuss some works that employs this method in geographical domains.

2.1 Navigation and Mobile Maps

In this work, *mobile map* stands for a map that is displayed by a mobile device connected to the internet and having localization capacities such as GPS. A modern smartphone is the typical example of such a device.

Montello (2005) defines navigation as the combination of wayfinding and locomotion. Locomotion being the mechanical part involved in the displacement (e.g. walking or driving). Wayfinding is the planning of this displacement and its constant replanning according to changing situation. Estimating travel time, finding waypoints or making decision about shortest route are all behaviour related to wayfinding (Montello and Sas, 2006). These authors identify two major issues related to map-based navigation. First, the opposition between the metric realism of topographical maps and the schematic utility of topological maps should be adressed with care, but it is clear that a quantifiable distance between points on a map is not always needed.

The second issue is the alignment of the map, which is described more in depth below in this chapter. The process involved in map based wayfinding involves several steps including deciphering symbol meaning, route planning, self-locating, and text/image/geometry rotation (Lobben, 2004).

Self-location, or orientation, is an important part of this wayfinding activity. Indeed, to successfully navigate to a goal, the navigator must know his or her relative position to this goal (Montello and Sas, 2006). This can be easy in a familiar environment or can necessitate the possession of a variety of tools such as a compass or a sextant as well as the knowledge to use them.

Lobben (2007) presents five abilities that are related to navigational map reading. *Map rotation* is the ability to mentally or physically rotate the map so that it fits the environment of the user. *Place-recognition* necessitates the creation of a mental parallel between the representation of the world (the map), and the world itself. *Self-location* is the ability to find oneself on the map based on observation of the environment. *Route memory* represents the capacity of the user to remember from the map a route or objects along the route. Finally *wayfinding ability* defines the capacity to use the acquired knowledge (from map or from previous visits) to optimize the route between two points.

In the case of mobile maps, the position of the user is constantly displayed. This is similar to the "you are here" (YAH) maps found in cities, parks or touristic places. Therefore the self-location part of the navigation process is bypassed. As a matter of fact, YAH maps reduce the time needed to complete the self localization step and modify the process involved (Kässi et al., 2013), however, a set of baseline must be respected for YAH maps to be efficient. Misalignment is a typical source of error for the user, and must be mentally or physically corrected (Klippel et al., 2006; Levine et al., 1984; Shepard and Hurwitz, 1984). The downside of displaying current user's position seems to be a weaker acquisition of route and survey knowledge (Münzer et al., 2006; Parush et al., 2007), probably due to the reduction of the cognitive load required to navigate.

(Meng and Reichenbacher, 2005) identified five types of maps that are currently in use. The view-only type can be presented on paper or on a screen. Its goal is to store information or to transfer it from the map producer to the final user. With analytical maps, the user is connected to a database and is able to select what information should be displayed on the screen. Exploratory maps also allow the user to modify the mapping content in order to facilitate research and thinking process. Web maps have hyperlinks that leads to related content and can be collaboratively enhanced. Finally, mobile maps joins the virtual and real world as they can be carried in the latter one and reflect its image in the first one. In fact, mobile maps bring maps to everyone at any time and anywhere. The map has become a one-way map that should perfectly fit the immediate needs of the user and discard any irrelevant information to be immediately understandable.

As the biggest obstacle to readability of mobile maps is the size of the display (Looije et al., 2007), and that it is now sure that the size matters in the user perception and efficiency (Chae and Kim, 2004; Raptis et al., 2013), a good mapping application should be able to limitate the information displayed to the minimum. The number of visual clutter should be as low as possible and emphasize greatly on what is relevant to the user (Setlur et al., 2010). To provide maps as close to the needs of the user as possible, the application must be aware of their context and adapt to its specific requirements (Gong and Tarasewich, 2004; Hong et al., 2009).

In this work, we will rely on (Dey, 2001)'s definition of the context: "Context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves". Clearly, time pressure is a part of this context and should be taken into account in regards to generate more efficient maps.

2.2 Spatial Abilities

According to the review by Hegarty and Waller (2005), spatial ability is "the ability to represent and process spatial information". Its study began in the early 20th century as a mean to test for potential affinities for technical branches. Spatial ability is often divided into several factors that can be individually tested. The two most common factors are *Spatial relation and orientation* and *Visualization*. The first one involves the subject in the sense that the body, or point of view, is important for solving the problem. The frame of reference must be taken into account. The second one implies the mental manipulation or transformation of objects. However, the results of tests related to one of the factor are usually highly correlated to the results of the other tests.

The paper folding test, which is used in this study, is presented as a visualization test to estimate the "ability to manipulate or transform the image of spatial patterns into other arrangements" (Ekstrom et al., 1976). The instruction sheet for this test is available in the appendixes at page 95. Illustration 7 at page 21 shows one of the twenty similar problems of this test. According to Tartre (1990) (as cited in Workman and Lee, 2004), there is four types of mental transformations depending on the visualized object and the process needed to mentally obtain the outcome. These transformations can occur from 2Dimensions to 2Dimensions, 2D to 3D, 3D to 2D and 3D to 3D.

The paper folding test is an example of a cross dimensional 3D to 2D transformation. The initial image is in three dimension because of the multiple layers of paper even if they are not directly represented. The outcome visualization is in 2D because it represents a flat sheet of paper.

Montello, (1993) proposes a classification of scale relatively to human body size. *Figural* psychological space refers to object that are smaller than the body. Typically maps or pictures are part of this group. *Vista* space represents the object which size is in the same order of magnitude as the body. Such spaces can be apprehended without locomotion. Rooms, courts or horizons are part of this category. *Environmental* space is greater than the body but can be apprehended by locomotion. To learn this space, time is needed. Finally *geographical* psychological space refers to vast areas that are much greater than the body. Locomotion does not allow a systematic visit of this zone. To learn this area, the user must rely on a *figural* space such as a map. Countries and bigger entities are example of this class. Environmental spatial abilities are defined by Hegarty and Waller (2005, p. 148) as "the abilities that require integrating spatial information over time and across the viewpoint changes associated with self-motion".

From this classification it appears that typical paper and pencil tests such as the paper folding test and wayfinding performances are based on different space families. The link between spatial ability measurement and environmental spatial abilities has been a subject of diverging studies (Hegarty and Waller, 2005). However, it seems that the individuals that score high on spatial ability tests are usually more able to read and learn knowledge from maps (Goldin and Thorndyke, 1981). This link between paper and pencil tests and larger scale capacities has been confirmed by Hegarty et al. (2006) who found that the result of spatial ability tests predicted an important part of the environmental-learning task performance, suggesting a partial dissociation between scales. Montello et al. (1999) also found a coherent patterns between the results of pen and paper tests and geographical tasks. Another important input in this field is made by the works of Lynn S. Liben. She was first interested in the water level test, in which the subject must imagine the water line inside a rotated bottle, (Vasta and Liben, 1996). Surprisingly, it was found out that the results to this tests were not only related to the age of the children as expected, but that many adults also had difficulties passing it successfully (Rebelsky, 1964). Afterwards, she decided to test for a link between tests for spatial abilities on one hand and wayfinding and map reading abilities on the other (Liben et al., 2010, 2008). Outcomes of these studies show that the results of the paper and pencil test explain a part, although not the whole, of the environmental spatial abilities, hence being coherent with Hegarty et al. (2006) findings.

Among the four tests used to predict field mapping performance, the paper folding test was the best predictor of success (Liben et al., 2010). For this reason this test was chosen for the present study as a potential predictor of map reading and wayfinding ability.

2.3 Time Pressure

Time is omnipresent in all cultures and holds a central place in a great variety of written works (Bluedorn and Denhardt, 1988). Time pressure occurs when time is lacking to complete a task. Time pressure is not well defined and is usually treated as a binary variable (e.g. high vs. low time pressure). High time pressure is sometimes described as when only fifty percent of the time necessary to complete the task is available (Hwang, 1994). This constraint has several impacts on human health, behaviour and cognition. For example, time pressure holds a role in the mechanisms involved in depressions (Roxburgh, 2004). But, in this work, we will focus on the consequences of time pressure on cognition and especially on its impact on decision making. It has been known for a very long time that response accuracy can be traded off for time and vice versa (Wickelgren, 1977). However, the time range considered in Wickelgren's (1977) report are very short, typically a few seconds or less. Our work will focus on longer periods which are better studied by researches on decision-making related to time pressure.

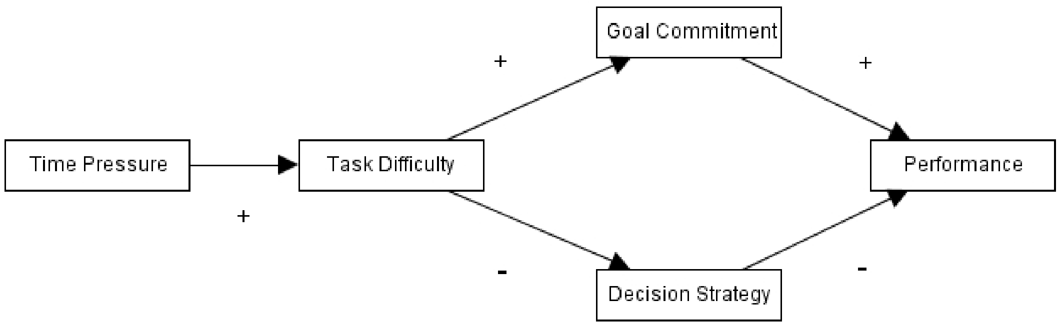

Illustration 1: Model of decision making under time pressure. +: positive impact; -: negative impact. Adapted from Hwang, 1994.

Illustration 1 shows a model of decision making under time pressure proposed by Hwang (1994). He explains his model as follow: applying time pressure to a task usually increases its objective and subjective difficulty. This increase in difficulty has two interesting consequences: increase in goal commitment and a negative effect on the decision strategies. The literature about effect of task difficulty on goal commitment is scarce, but Hwang cites a meta analysis of 78 goal-setting studies that found this effect (Wofford et al., 1992). This increases in goal commitment should then positively influence performance (Locke et al., 1988). On the other hand, Hwang predicts a deviation towards more heuristic, less optimal, strategies when time pressure increases. This ultimately leads to worse performances (Ahituv et al., 1998). Subjects under time pressure focus on the negative aspect of the information and the possible losses ensuing their decision. Decision taken under time pressure are thus less risky (Ben Zur and Breznitz, 1981; Maule et al., 2000).

On the overall, the time pressure seems to have a non linear effect on performance. Mild time pressure could increase performance until a tilting point when the time pressure is too high and begins to impair performances (Andrews and Farris, 1972; Coeugnet, 2011; Kerstholt and Willems, 1993; Wilkening and Fabrikant, 2011). Following the model proposed by Hwang, this means that under low or mild time pressure, the increase in goal commitment prevails. But when time pressure becomes greater, the strategies quality loss supplant the goal commitment gain and the performance drops.

Joining decision making theory, time pressure and wayfinding is rather rare and the studies on the subject are scarce. In a wayfinding task held in a virtual building, it was found that participants under time pressure took less time to reach the target, but made error in their itinerary, subject non submitted to time pressure took more time for reflection (Srinivas et al., 2010). The works by Wilkening and Fabrikant (Wilkening and Fabrikant, 2011, 2013; Wilkening, 2010) are also making a link between geography, decision making and time pressure. They found that preference towards abstract maps increased for user under time pressure. Accuracy and confidence had a U shaped form with a maximum under mild time pressure. They also showed that, for 3D map browsers, interaction tools are less used when under time pressure. However, they stopped the task after the route was planned. Our work will incorporate the route execution in the experiment because it is an integral part of the wayfinding task (Ishikawa et al., 2008). Concerning mobile maps, while it is clear that time pressure should be taken into account as one of the cognitive resource of the user (Baus et al., 2002), no study was found tackling this particular subject.

2.4 Skin Conductance Level and Skin Conductance Response

In 1907, Binswanger published an article in a book directed by Jung about "*psychogalvanic phenomenon in* [words] *association experiments*" (Jung, 1919, p. 447)[2]. He already wrote that the idea to connect psychological changes with skin conductance is not new, at least some tests have been reported in 1888 by French psychologist Vigouroux. Binswanger describes an experiment held at the Zürich university psychiatric clinic that aimed to show relation between skin conductance response and words stimuli.

When submitted to an emotional stimuli, the eccrine sweating of palms, soles and axillary regions augments. This reaction probably evolved as a strategy to avoid slipping during a stressful flee run or climb (Adelman et al., 1975). Eccrine glands are typically controlled by the sympathetic nervous system. However, recent research showed that in the case of emotional sweating they could also be controlled by adrenaline (Wilke et al., 2007). This modification in sweat quantities leads to a change in electrical conductivity of the skin that can be measured with electrodes. In this study we use the BMS SmartBand device (Papastefanou, 2009) to measure the skin conductance level.

The book chapter written by Figner and Murphy (2010) is proposing a very complete review and guidelines for electrodermal conductivity recording and analysis. Skin conductance refers to the capacity of the skin to conduct an external electrical current applied to it. Skin conductance can be split in two phenomena: phasic and tonic. Tonic part

2 The year differs because of the only edition available online.

of the signal is the longer term effect and is usually known as skin conductance level (SCL). Phasic part represents the short term variations in the signal, typically showing the skin conductance response (SCR, channel E in illustration 2). The raw recording (channel B in illustration 2) contains both of them and they should be isolated to be interpreted. The SCL is not directly related to stimuli, but shows an overall arousal level, or even increases linearly throughout the day regardless of the activity of the subject (Hot et al., 1999). On the other hand, SCR can be observed directly after an external stimulus (but can also appear sometimes due to internal stimulus). SCR can be computed from the raw signal using a derivative function over time.

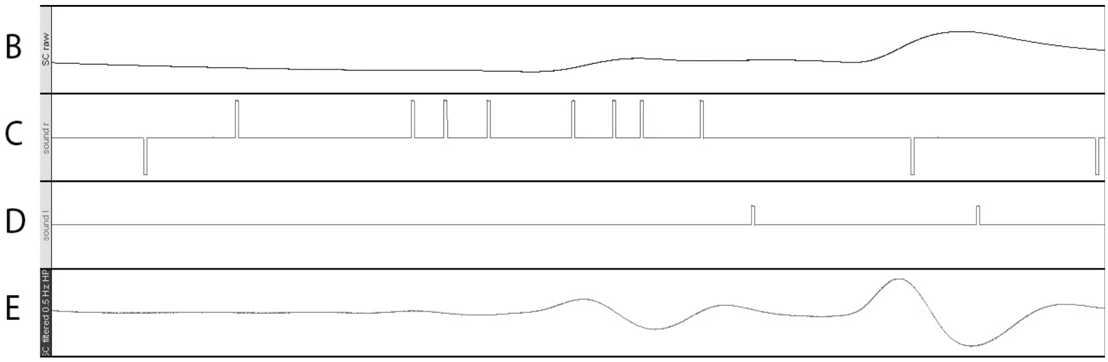

Illustration 2: Typical signal from skin conductance study. B: raw signal; C,D: stimuli; E: SCR. Adapted from Figner and Murphy, 2010.

Related to geography, several studies have been done using the skin conductance. It was found that a relation exists between the conscious emotion and the SCR of a user when walking in a city (Hogertz, 2010). An example of this can be found in the illustration 3. The negative feeling reported by the user are shown in red on the map on the left. The SCR recordings are shown in the map on the right. A clear relation appears between the two maps.

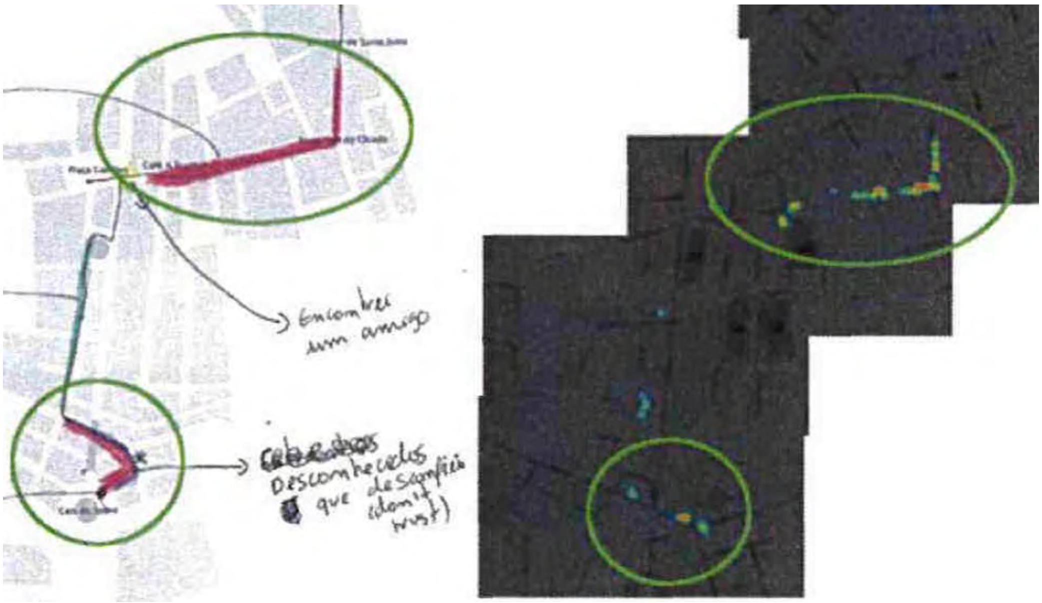

Illustration 3: Comparison of emotional experience described by a user (left) and the SCR recorded at the same place (right). Adapted from Hogertz, 2010.

In another study, it was found that when a subject is confronted with a series of maps representing the same area but with varying aesthetic, different levels of SCR are recorded (Fabrikant et al., 2012). In this study the authors corrected the SCR to obtain Phi-score, following a method proposed by Lykken (1972). To quantify the strength of the emotional response, the authors summed across participants the number of Phi-scores peaks following each stimuli.

Finally, in a series of paper the possibility of using skin conductance recording as a tool to emotionally map the city with a town planning point of view is explored (Bergner et al., 2013, 2012, 2011; Zeile et al., 2009). It comes out that the data produced by the physiological recording tools during exploration of a city neighbourhood is usable to describe the localized emotional responses of the users. This information can then be interpreted to assess the neighbourhoods of the city that requires specific attention.

It is interesting to note that the combination of skin conductance data coupled with GPS tracks is producing relevant information about the emotions felt at a known geographical position. In this study, the physiological data will also be compared with data concerning the interactions of the user with the mobile map. The analysis of all this data will help us to understand how the user deals with the peaks of stress in terms of usage of mobile maps.

3 Method

In this chapter we will describe how information was gathered in order to answer the research questions. This will be done in a chronological order, the part that was done first will be explained first.

3.1 Application for Android

In order to show the participants the points they have to visit, an application was written for an Android phone. This application was also designed to collect data simultaneously. The application performs the following:

- Display a map with the goal points that the users must visit and the origin & final point.
- Inform the users of their progression with a pop-up window and by removing the points that are already visited.
- Record the position and the time.
- Record the interactions between the user and the map.
- Film through the inbuilt webcam.

Each of these points will be detailed below and the central part of the code can be found in the appendix (p.79) of this work.

Android was chosen mostly because the author of this work already had some experience in Java programming and therefore the learning process to be able to write an application was easier. At first an attempt was made to develop the application using the MIT's App Inventor[3]. This web page allows the users to create an application by sliding its element to a smartphone representation and to specify the logic behind by assembling “logical blocks”. However, this was unsuccessful due to the impossibility of using the Google Maps Android API or any other efficient map within this framework. Programming was therefore done using Eclipse integrated development environment[4] adapted for Android with the Android Development Tools[5].

The smartphone used for development as well as for the experiment was a Samsung Galaxy SIII mini with Android OS v4.1.2 (Jelly Bean) installed (see Chapter 3.3.1 for more information).

3 http://beta.appinventor.mit.edu/ [visited last the 04.06.2013]
4 http://www.eclipse.org/ [visited last the 02.03.2013]
5 http://developer.android.com/sdk/installing/installing-adt.html [visited last the 04.06.2013]

The application was named *IrchelRun* as the experiment took place nearby the Irchel park in Zürich, Switzerland. It was designed with three activities (activities in smartphones applications can be understood as the screens displayed). The first activity that appears when the application is launched displays the current user's number and a button to start the experiment. From this activity it is possible to access, through the menu button, the *UserNew* activity designed to create a new user for the study. When a new user is created, the map is reset, the current user's number increased by one and the application automatically returns to the home activity waiting for the experiment to begin. When the start button is clicked, the Map activity is called and the map is displayed. At that point all the recordings start. The application was designed so that even involuntary exiting is not a problem and that no data can be lost. When the user comes back to the map after quitting the application, the map is resumed with the same extent as before. The points already visited are not shown again.

3.1.1 Display the map and the markers

The map displayed by the application is Google Maps, through the Google Maps API for Android v2. This map was chosen because it is very commonly used (250 millions mobile users according to Google[6]) and because of its simplicity of integration in an application.

To display a map in an android application, first of all an API key must be asked at google API console[7]. This API key allows Google to control what application is using its map and to limit the number of access for non paying users. The key is related to a code that is unique for each application.

Once the API key is obtained, the map is displayed within an adequate fragment of the display and nearly full screen. The points to visit as well as the adequate buttons are then added to the map. The colour of the points markers is defined at the beginning of a new trial. The colours are based on a 0 - 360 hue wheel. As the code was written before the exact number of points to be displayed was known, it was designed to accept any number of input point. Therefore the ideal colour of the points could not easily be predetermined and hue attribution was automated. The first point's hue was set to 55 and 60 was added for each forthcoming point. If the hue would exceed 360, the modulo of this new value by 360 would be taken for the new value and the process repeated. This is an easy process, but it leads to colours that might be problematic for readability, especially if the participant is subject to colour blindness.

6 http://www.google.com/enterprise/mapsearth/products/mapsapi.html [visited the 04.06.2013]
7 https://code.google.com/apis/console/?pli=1#project:430113164496 [visited last the 04.06.2013]

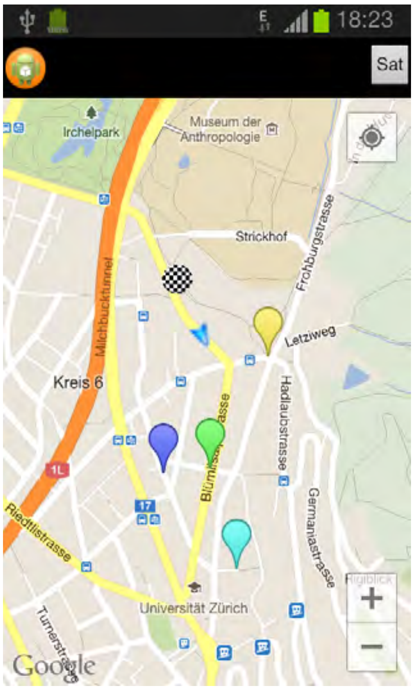

Illustration 4: Application's screen at the beginning of the experiment

At the beginning of the experiment the map was centred to 47.391769 North and 8.548304 East and zoomed at a level of 15. This allowed the study zone to be entirely visible on the screen. The activity orientation was locked to portrait and the screen was prevented from going to sleep. The user can use the map as a normal smartphone map i.e. zoom, pan, rotate and centre the map to current position. It is also possible to switch between map and satellite view. For the zoom, the pan and the rotate it is possible to use the classical fingers moves on the tactile screen.

3.1.2 Inform the user of his or her progression

The user was informed of the progression by the default Google maps blue arrow visible about a centimetre below the start&finish point in Illustration 4. When a user reaches a goal point, a pop-up window shows up and provides informations about the number of points left. Simultaneously, the phone vibrates for about half a second. Once the user dismisses the pop-up windows, the map is reloaded without the reached point. If the point reached is the last one, the user is invited to head back to the starting point. To achieve this a location listener was set to fire a method when the position of the smartphone is within a twenty meters radius of any goal point. This distance calculation was done using the *distanceTo()* method of the class *Location* from the android.location package. This class bases the calculation of distance on an inverse solution of geodesic on the ellipsoid[8] (Vincenty, 1975).

8 https://android.googlesource.com/platform/frameworks/base/+/4118012da9a22694b3353040a485f8cdc27e2f17/location/java/android/location/Location.java [last visited on 05.06.2013]

The trigger distance of twenty meters was chosen after preliminary trials. It is sufficient to take into account the typical five meters inaccuracy of the GPS as well as for preventing the user to have to cross the street or zigzag unnecessarily to catch the point.

3.1.3 Record the position and the time

A method was implemented to write a new line in a file every five second to store the current time and location. The method also writes the source and accuracy of the information. The source was later set to be taken into account only if emanating from the GPS because WiFi and antenna location informations are too inaccurate to be of any help in this case. The method also writes the user number and the time pressure state of the user. Finally, if the location corresponds to a newly reached goal point, a comment is added at the end of the line. Headings are generated on the creation of the file. A typical line of this output file looks like this :

```
UserNb;TimeStamp;Latitude;Longitude;Accuracy;Provider;TP;Comment
2;1366266012619;47.39392845891416;8.547697132453322;5.0;gps;false;
```

Note that the time stamp is in milliseconds and in UTC which is not the case for the data collected from the SmartBand.

3.1.4 Record the interactions

The ways the user could interact with the map are: zoom, pan, rotate and switch map/satellite view. The first three are recorded through the camera change listener of the map. In this case, the camera means the point from where the map is shown. If the user pans, the new centre of the map is recorded. If the map is rotated, the new bearing (in degree from north) is noted down. Finally when the user zooms in or out, the zoom level is saved. The zoom ranges from 0 (world in approximatively 256 pixels) to 21 (world in approximatively $256 * 2^{21}$ pixels)[9]. Each time one of this action is performed, a new line is written in an output file. A new line is also written in this file each time the user switches between map and satellite view.

The fields that are not concerned by the action that generated the line are either left empty or filled with easily identifiable values (e.g. if the user pans but does not change the zoom neither the orientation of the map, the new line will have -9999 for the zoom level and -8888 for the bearing).

The file also contains the user's number, the time of the recording and the number of moves the user required from the map. This last value is in fact equivalent to the number of lines (except when the application is quitted and restarted) and was added for development purposes only. Headings are generated on the creation of the file. A typical line of this output file looks like this:

9 See for example http://www.cnblogs.com/hbf369/p/3261503.html [last visited on 23.06.2013]

UserNb;TimeStamp;TargetLatitude;TargetLongitude;ZoomLevel;Bearing;NbOfCameraChanges;Comment

25;1369062380211;47.39108093352226;8.548254109919071;15.530067;-8888.0;3;

One can see here that a new zoom and a new map centre were required simultaneously, but that the bearing did not change. This simultaneity happens usually when a finger move is used for zooming because a slight drift of the map centre is inevitable (see Chapter 4.1.4). Again, the time stamp is in milliseconds and in UTC which is not the case for the data collected from the SmartBand.

3.1.5 Film through the inbuilt webcam

During the whole time of the experiment the user was recorded through the inbuilt webcam. The webcam is the camera that is on the same face as the screen of the device. Therefore when the participant watches the screen, he or she is also facing the webcam.

The use of the phone's camera requires several steps, but is rather well documented on the Android programming web page[10]. The recording quality was set to low to spare memory space.

The only issue encountered while developing this part of the application is that Android applications are not supposed to use cameras without showing a preview of what is being recorded on the screen. To circumvent this problem, the preview was set to a 1×1 pixel frame at the bottom left of the *map* activity and is hence invisible but present[11].

3.1.6 Application's known issues and leads for improvement

The main issue of this application is an occasional loss of accuracy along time. The position recorded and shown on the map sometime seemed to move slower than the user. If the user stops, the recorded and shown position would not catch up but stop as well. It leads to a drift from the recorded position regarding the actual one. This did not happen every time and the cause remains unknown. A possible source is the recording of information that could potentially slow the phone by using cache memory. However, this problem can be temporarily resolved by quitting and restarting the application and was therefore not significantly disturbing. Example of this problem can be observed by comparing Illustrations 12 and 13 at page 29.

As stated in chapter 3.1.1, the colour of the target points could have been better. Instead of calculating the hue's value, the colours should have been picked from a satisfying and safe list.

The camera recording is sometime difficult to interpret because of the back light. A finer setting of the luminosity level, or even a face detection based balance of the whites could have helped.

10 http://developer.android.com/guide/topics/media/camera.html#capture-video [last visited on 05.06.2013]

11 http://stackoverflow.com/a/3881027/2199538 [last visited on 05.06.2013]

Once, for an unknown reason, the application did not record the GPS track during the experiment. This was apparently solved by reinstalling it and never happened again.

3.2 Participants

26 (18 males (69.2%)) participants took part in the study. One was considered as only partially valid due to a misunderstanding of the instructions. The data collected from this participant from the spatial ability test were used anyway because they were not concerned by the problem. The age ranged from 21 to 57 years old with a mean of 28.3 and a standard deviation of 9.3.

Among these participants, 23 owned a smartphone or had regular access to one. 11 of these smartphones were running Android and 12 iOS. No participants are regularly doing orienteering races or geocaching. Two participants sometimes work as delivery men (one by bike and one by truck), which involves a similar task to the one in this experiment.

Most of the participants were students (21), from which 14 are studying geography at the University of Zürich. The current number of semester of study ranged from two to twelve, with an average of 6.9 semesters. The fields of study for the other participants were architecture, civil engineering, social work and environment. The others participants' occupation were nurse, marketing assistant, brewer, waitress and pharmacist.

Nearly no participant has been to the zone of the experiment before, and the ones who did did not knew it well.

25 of the participants stated that they usually (but not necessarily only) use Google maps when they need a web mapping service, 9 use Maps.search.ch.

3.3 Hardware

3.3.1 Smartphone

The smartphone used for this experiment was a Samsung Galaxy SIII mini. Also known as GT-I8190. It is a touchscreen phone first released in November 2012. Its screen is of 4 inches (100 millimeters) of diagonals with a resolution of 800 by 480 pixels. It weights 111.5 grams. During the experiment the lightning of the screen was set to three fourth of the maximum.

The webcam through which the video was recorded is of VGA quality.

3.3.2 Smartband

The device used in this experiment to record physiological data is named Smartband by the firm *Bodymonitor*[12] that produce it. According to the company web page, it measures skin conductance, skin temperature, environment temperature, cardiac pulsation and movement. In this study, only the skin conductance was used. The skin conductance is measured by two

12 http://www.bodymonitor.de/Technologie [last visited on the 14 August 2013]

gel coated electrode placed on the inside of the wrist. The data is taken at a 10 Hz frequency and logged in the internal memory. Before the experiment the Smartband can be synchronized with a smartphone via the bluetooth technology so that the timestamps of the recordings match.

Example of studies in which similar material are used can be found in the works such as Bergner et al. (2011) in a city planning and emotional barrier study; Fabrikant et al. (2012) in a map colour scheme comparison; Hogertz (2010) in an analysis of the emotion encountered along a walk in the Lisbon streets; Ohtaki and Papastefanou (2010) in a short indoor study presenting the possibilities of multi-sensory studies, note that in this study the device used to record physiological data differs; and Papastefanou (2009) who explores the possibilities of this technology regarding for empirical social studies. G. Papastefanou, which appears in most of this studies as a co-author or author, is in fact the main person behind the Bodymonitor company.

Illustration 5: The inner side of the Smartband with two electrodes.

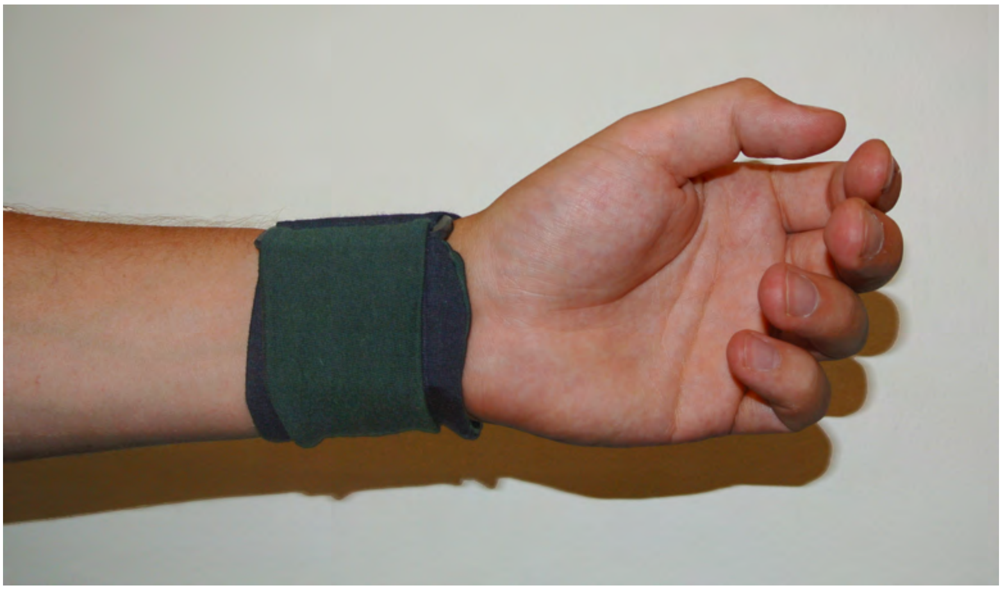

Illustration 6: The smartband mounted on a wrist. Note that it is very little invasive.

The great advantage of this technology over the former available devices is its very small size and weight. It is worn on the wrist and hence does not disturb the study participant as much as one that necessitates electrodes in the palm for instance.

3.4 Experimental Design

The experiment only independent variable was the time pressure state. Time pressure was induced by a different scenario of the task. The participants without time pressure were told they were visiting some touristic places. Participants under time pressure were told that they were about to arrive late at a job interview. Scenarios are available in the appendix at page 96. The scenario of the job interview was chosen because it appears to be a powerful tool to put people under pressure (Kirschbaum et al., 1993).

The Table 1 shows the variables that were taken into account in the design. The most important are the independent and dependent variables because the goal of the study is to measure the effects of the first one on the seconds. The control variables are external factors that might affect the output but that are kept within a reasonable range. In this case it means that the zone of study remains constant. Random variables are possible sources of variations in the output, but as they are randomized they are likely to be secondary. Confounding variables are the inputs that can bring a serious bias on the results, however in this experiment none of the users had a good knowledge of the environment. On the other side, the other possible behaviours are variables that are likely to change dependently of the circumstances but that we are not primarily interested in (Martin, 2007).

	Circumstances	**Behaviours**	
Independent Variables	Time Pressure	Distance walked Time spent reading map Use of the map (Zoom, …)	**Dependent Variables**
Control Variables	Environment (Irchel)		
Random Variables	Weather Hour of the day User's data (age, …) Paper Folding Test Results	Speed Time to complete the task	Other Possible Behaviours
Confounding Variables	Knowledge of the environment		

Table 1: Variables in the user study, adapted from Martin (2007)

A between-subject design was chosen. This design presents the advantage of being free of the learning effect inherent to within-subject design. This effect would probably have necessitated to move to another area in the middle of the experiment and thus to excessively prolong the experiment.

A paper folding test was conducted so that the influence of spatial ability can be compared with the influence of time pressure.

3.5 Procedure

The experiment took place between April and May 2013. The participants were free to chose the day and time that suited them by registering online. Once registered they were sent a confirmation email containing the consent form for the case they wanted to have more informations and to possibly gain some time during the experiment.

Before a participant arrived, the experimenter systematically synchronized the time of the SmartBand with the smartphone. This was done through a bluetooth dongle and an android application provided with the SmartBand.

The beginning of the experiment took place in a study room normally lit and heated. The participant was invited to sit at a table and was given a printed version of the consent form (appendix p.90) with the instruction to read and sign it. A copy of this consent form was given to the participant.

After that, the experimenter asked the participant to fill an online background questionnaire. This questionnaire was displayed on the smartphone that is also used for the experiment. The idea behind this was to familiarize a bit the user with the device, especially for those who did not own one. A printed version of the background questionnaire can be found in the appendix at page 93.

Once the questionnaire was filled, the participant was provided with the instructions for the paper folding test. The experimenter asked the participant if he or she had any questions about the test before starting it. The test was constituted of two pages of 10 problems each. The participant had 3 minutes by page and could not switch to the next before the first one was completed or that the time ran over. Illustration 7 shows the problem number seventeen of the paper folding test. The instruction sheet for the test is to be found in the appendix at page 95.

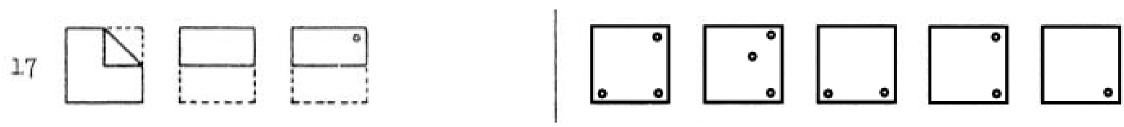

Illustration 7: Problem 17 of the Paper Folding Test. Correct answer is the rightmost (E).

The following step was the setting up of the Smartband on the wrist of the non-dominant hand. Note that the Smartband was not turned on yet. Disposable electrodes were used and no pretreatment of the skin such as water or alcohol cleaning was done. Fixing the electrodes at that point of the experiment, about five minutes before starting the Smartband, allows the gel to soak into the skin and guarantees a good electrical connection (Figner and Murphy, 2010).

The next part of the experiment took place outside, only during daylight and without precipitation. The starting place of the trial was situated about three hundreds meters from the above cited room. The neighbourhood where the experiment took place is quiet and residential. Most of the streets are equipped with pavement on both sides and the traffic is sparse enough to allow crossing at any point without waiting time or danger. This neighbourhood was well adapted because a pedestrian can wander it without paying too much attention for his or her own safety regarding traffic. A panoramic view of the starting place and a picture of a typical street of the area are shown in Illustration 9 and 10 respectively.

Illustration 8: Panorama of the starting place. The starting place is on the left side of the picture, behind the brown signs. The street in the middle is Langensteinerstrasse, direction south-east.

Illustration 9: A typical street of the area of the experiment. In this case, Blümlisalpstrasse near the crossroad with Schäppistrasse and towards south.

Once the starting place was reached, the experimenter gave the instructions for the next part of the study to the participant. These instructions were written and described the scenario (with or without time pressure, see Chapter 3.4). Informations were also provided on how to use the application. The two versions of the instructions are available in the appendix at page 96. Again the participant was encouraged to ask questions if he or she had any doubt on the experiment. The Smartband was turned on while the participant was reading. When the participant declared to be ready the experimenter handed him or her the smartphone with the map activity (see Chapter 3.1) open and told them that the experiment was started.

During the trial the experimenter followed the participant at approximatively ten meters and refused to help or talk except if the participant had technical problem with the application (e.g. unintentional pressing of the home or return button). If the participant tried to engage in conversation the experimenter increased the following distance. The experimenter took some notes during the experiment about events or user's strategies that were found interesting.

When the participant reached the finish point, the experimenter took back the phone and switched off the Smartband. The participant was invited to remove it. The experimenter led the participant back to the above mentioned room to complete the final questionnaire. This last questionnaire asked the participant about his appreciation of the difficulty of the task and about the time pressure felt. Some space was also provided for more general comments on the experiment. Participants who wanted to be kept informed of the study were asked to leave their e-mail on this form. An example of this questionnaire can be found at page 98 in the appendix.

Overall, the experiment took approximately fifty minutes from which twenty for the indoor part.

4 Results

4.1 Variables

This sub-chapter will introduce the variables used afterwards and explain how they were collected and processed.

4.1.1 Nb of Glances at the Phone, Total Time Spent Looking

These two variables were derived from the video recording of the experiment obtained by the inbuilt webcam (see Chapter 3.1.5). A small Java program was written in order to help counting the number and duration of each glance at the screen. Each video was watched at a double speed, each time the participant starts or stops staring at the phone, the space bar was pressed. This action is recorded by the Java program. Once the video reaches its end, the q key is pressed and a summary of the number of glances, the time spent looking at the screen and the total time is displayed. In parallel a line is written in a file each time the space bar is hit. This line contains the time stamp of the hit and the corresponding action. The risks of imprecisions for this data results from two main sources. First, the possibility that the key was pressed too late or too early when the participant started/stopped staring at the screen. Even so the data should still be accurate overall because a too slow starting is probably linked with and offsetted by a delayed stopping. Secondly the recording is sometimes difficult to interpret because of back light that makes the participant's face look totally dark and therefore difficult to be sure if he or she stares at the screen or somewhere else. However, complete impossibility to ascertain participant's behaviour happened only a limited number of times. When it happened I opted for the most likely behaviour based on previous observation and current image.

		Nb of Glances at the Phone	Total Time Spent Looking [s]
N	Valid	25	25
	Missing	1	1
Mean		110.28	566.56
Median		117.00	555.00
Std. Deviation		57.465	248.806
Minimum		33	183
Maximum		269	1286

Table 2: Descriptives statistics for Nb of Glances at the Phone and Total Time Spent Looking

4.1.2 Total Time

Total time could have been obtained by several means such as the difference between the first and the last GPS recording or by timing the experiment in the field. The chosen method is based on the video durations as displayed by the video player used. The downside of this method is that the video takes a few second to start (about five) when the map activity is launched. Hence the total time obtained is in fact a few seconds shorter than the real total time. However, I believe this has no major impact on the analysis, first because five seconds is only approximately 0.4 percent of the shortest total time. Secondly because a large part of the first few seconds are used to hand on the smartphone to the user.

N	Valid	25
	Missing	1
Mean		1519.24
Median		1495.00
Std. Deviation		248.554
Minimum		1183
Maximum		2392

Table 3: Descriptive statistics for Total Time

4.1.3 Time per Glance, Ratio of Time Spent Looking at the Phone, Nb of Glances / Total Time

These variables are relative and ensue from the ones above which were absolute. *Time per Glance* is calculated as follow:

$$Time\ per\ Glance = \frac{Total\ Time\ Spent\ Looking}{Nb\ of\ Glances\ at\ the\ Phone}$$

Ratio of Time Spent Looking is calculated as follow:

$$Ratio\ of\ Time\ Spent\ Looking = \frac{Total\ Time\ Spent\ Looking}{Total\ Time}$$

Finally Nb of Glances / Total Time calculation is implicit and is a practical way of obtaining a relative number for the number of glances.

		Time per Glance [s]	Ratio of Time Spent Looking at the Phone	Nb of Glances / Total Time
N	Valid	25	25	25
	Missing	1	1	1
Mean		5.5669	.3702	.0716
Median		5.0313	.3789	.0717
Std. Deviation		1.68057	.13366	.03172
Minimum		3.75	.12	.02
Maximum		10.81	.63	.12

Table 4: Descriptive statistics for Time per Glance, Ratio of Time Spent Looking at the Phone and Nb of Glances / Total Time

4.1.4 Nb of Interactions, Nb of Interactions / Total Time

The number of interactions represents the number of times the participant touches the screen of the phone in order to modify the current view of the map. This can be zooming in or out, panning, rotating or switching between map and satellite. The application incorporated a listener that recorded in a file every interactions (see Chapter 3.1.4). It turned out that the data could not be used directly because of some unexpected outputs. When a user uses the + or – button to zoom in and out, the application records only one line of data, going directly from one level of zoom to the next one. But if the participant uses his or her fingers to zoom in or out, then tenth of lines are written in a very short time period (typically less than a second). In fact using the fingers split up the movement into many small zooming. Moreover some panning is recorded as well because it is nearly impossible to zoom with the fingers without slightly moving the map. In the same manner, panning actions were divided into several steps of a few hundreds milliseconds.

To solve this problem I decided to take into account only the lines that occurred more than half a second before the next one. Five hundred millisecond is a good break criteria because it is long enough to surely eliminate the noise described above and short enough not to misinterpret close but distinct interactions. This was done through a MATLAB script available in the appendix at page 100. The variable *Nb of Interactions* is the number of lines in the file generated by this simplification process. The data would have been rich enough to allow a differentiation between the types of interactions, but no reason was found to justify a separation of the different types of interactions in the analysis. Only the users that switched at least once to the satellite view were listed (see Chapter 4.11).

The variable *Nb of Interactions / Total Time* is a relative variable obtained by dividing the absolute total number of interactions by the time needed in seconds by the participant to complete the task.

		Nb of Interactions	Nb of Interactions / Total Time
N	Valid	25	25
	Missing	1	1
Mean		82.80	.0565
Median		85.00	.0541
Std. Deviation		57.410	.03938
Minimum		8	.00
Maximum		218	.15

Table 5: Descriptive statistics for Nb of Interactions and Nb of Interactions / Total Time

It is interesting to note the very big difference between the maximum and minimum of the number of interactions (table 5). The minimum represents a user that nearly did not touch the map. It was in fact possible to successfully complete the task without modifying the initial view (see Illustration 4, page 15). On the other hand a user that prefers a high level of zoom is condemned to constantly adjust the view to fit current needs, hence generating a large number of interactions.

Finally it is worth mentioning that there is no correlation between these two variables and the glances at the phone variables. A user that watches frequently at the screen does not necessarily touch it as often.

4.1.5 Distance Travelled

Distance travelled is computed from the GPS output of the Smartphone (see Chapter 3.1.3). This information was processed through a MATLAB script in order to obtain the distance travelled by the user. This script is available in the appendix at page 101. The distance is calculated using the haversine function because it is suitable for small angles (Sinnott, 1984). The radius used is calculated from the equation described in[13] and is of approximately 3667 kilometres for the latitude of the experiment. The MATLAB script used to calculate the distance between two points can be found in the appendix at page 101. The total distance for each user was then computed using an iteration of this script.

Possible imprecisions come from the GPS accuracy which is typically of five meters. Another source is the possible difference between the calculated earth radius based on the ellipsoid and the actual one. The slope also is a factor of error as it is not taken into account in the calculation. Finally, as described in Chapter 3.1.6, a drift occurred sometimes between the actual path and the recorded one.

In order to quantify the potential error, the routes were redrawn using ArcGIS and their length computed (see Table 6). This new variable was named *Distance Travelled Redrawn* The average difference between the two methods is 76 meters, which is about four percent of the shortest path registered by the GPS. Another point to take into account is that the difference always but once goes in the same direction, i.e. the GPS track is shorter than the equivalent route drawn on ArcGIS. To see if this error could have had an influence on the statistics some tests were conducted. A 0.943 correlation between the two variables with a significance level $p < 0.001$ was found, indicating that their behaviour are nearly identical. Further on, it came out that none of the t-tests presented in Chapters 4.3.2, 4.4.2 and 4.5.3 would have been significant for the *Distance Travelled Redrawn*. This variable was therefore left aside and only the *Distance Travelled* (i.e. obtained by the GPS track) was considered.

13 http://gis.stackexchange.com/a/20250/19039 [last visited on 12.06.2013]

		Distance Travelled [m]	Distance Travelled Redrawn [m]
N	Valid	25	25
	Missing	1	1
Mean		2000.72	2077.04
Median		1947.00	2033.30
Std. Deviation		161.482	168.622
Minimum		1828	1932
Maximum		2460	2645

Table 6: Descriptive statistics for Distance Travelled obtained by GPS tracks (left) and after redrawing in ArcGIS (right)

The users 11, 17, 16, 24 and 25 took the same and shortest route of this experiment. Based on the redrawn routes on ArcGIS, the length of this route ranged from 1932 meters (user 16, Table 6: Minimum in the second column, Illustration 10) and 1990 meters with an average of 1970 meters. The range comes from imprecisions in the digitalisation of the routes because they were all redrawn separately even if identical. The users 9, 15 and 23 took a similar route with an average of 1966 meters and a minimum of 1955 meters. The shortest route found here is very similar in distance to the best route found by a web page that provides a travelling salesman problem solver based on Google maps[14], displayed in Illustration 11. This web page proposes a solution that is 1972 meters long once drawn on ArcGIS. No participant used this route.

For an unknown reason the application did not record the GPS track of the user 21. The track was drawn by the experimenter on ArcMap directly after the experiment and both *Distance Travelled* variables computed from this data.

14 http://gebweb.net/optimap/ [last visited on 13.06.2013]

Illustration 10: User16's itinerary: The shortest itinerary of the study. Users 11, 17, 24 and 25 took the same itinerary.

Illustration 11: The theoretical shortest itinerary calculated from http://gebweb.net/optimap/

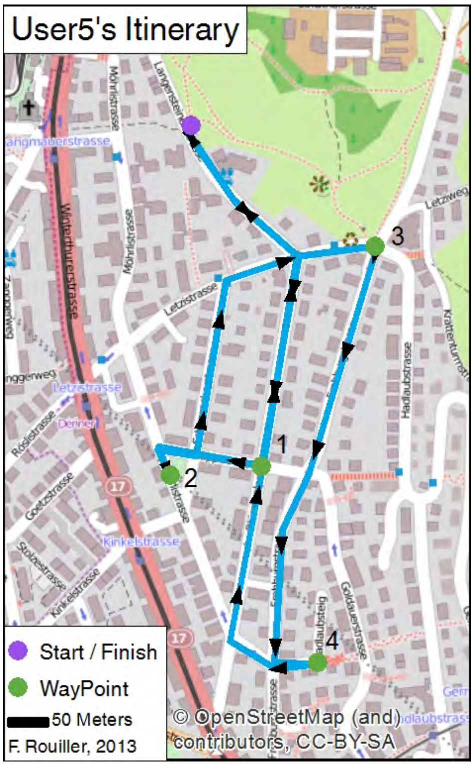

Illustration 12: User5's itinerary: The longest itinerary. The points are labelled in the order of visit.

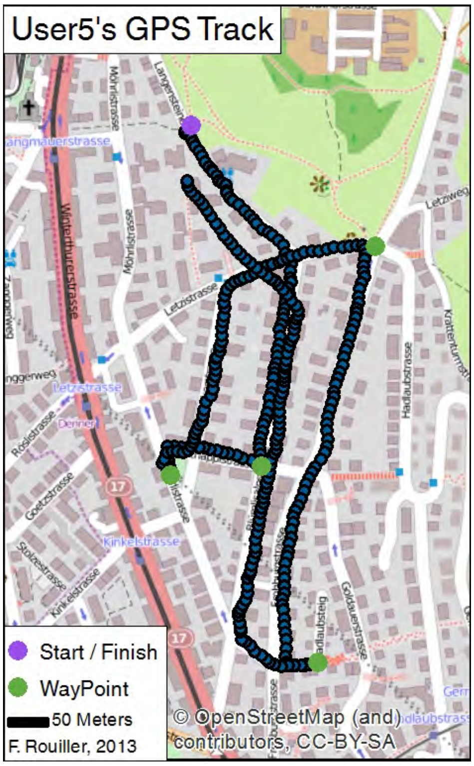

Illustration 13: User5's GPS track. Note the drift toward south near the finishing point.

On the other hand the participant number five did the longest itinerary with 2645 meters (Illustration 12). This itinerary is clearly not optimal. The participant first goes to the two points in the middle, then goes back to the northernmost point, walks towards the southernmost one and finally heads back to north to reach the finish mark. Illustration 13 shows the GPS coordinates recorded during the same experiment. Note the drift that starts just ahead the last turn before the finish point. This drift is due to an issue in the application that was discussed in Chapter 3.1.6.

4.1.6 Major Errors and Suboptimal Itinerary

This binary variable is thought to list the noticeable errors that occurred during the experiment.

The itineraries of all users were observed and the one that did errors of more than a few meters were listed. In this case, errors are to be understood as going in a direction that is clearly not the wanted one, usually leading the user to walk back once the error is noticed. This was confirmed by notes taken during the experiment when an error was observed. Mostly those errors were taking the wrong direction at the beginning of the experiment or at a crossing. The user5 that did a very suboptimal itinerary was also taken into account for this variable.

Five users did a major error or a very suboptimal itinerary.

4.1.7 How Difficult Did You Find This Task?

This variable is obtained from the last questionnaire the user had to fill. This questionnaire is available in the appendix at page 98. It represents the self rated difficulty to complete the wayfinding task. The user answered on a Likert scale (Likert, 1932) from *1: very difficult* to *5: very easy.* To ease the treatment of data and for homogeneity with time pressure self rating, the scale was reverted afterwards and is therefore now to be read as *1: very easy* to *5: very difficult*.

N	**Valid**	25
	Missing	1
Mean		1.840
Median		2.000
Std. Deviation		.7461
Minimum		1.0
Maximum		3.0

Table 7: Descriptive statistics for How Difficult Did You Find This Task ?

Note that no participant found the task more difficult than *3: Neutral.*

4.2 Normality test

It is important to calculate the normality because most of the usual statistical analysis assume that the sample is normally distributed.

To test the normality of the dependent variables, a Kolmogorov-Smirnov test was used to see if the population was significantly different from a normally distributed population.

		Nb of Glances at the Phone	Total Time Spent Looking [s]	Total Time [s]	Time per Glance [s]	Ratio of Time Spent Looking at the Phone
N		25	25	25	25	25
Normal Parameters[a,b]	Mean	110.28	566.56	1519.24	5.5669	.3702
	Std. Deviation	57.465	248.806	248.554	1.68057	.13366
Kolmogorov-Smirnov Z		.737	.721	.833	.936	.453
Asymp. Sig. (2-tailed)		.650	.676	.492	.345	.986

		Nb of Glances / Total Time	Nb of Interactions	Nb of Interactions / Total Time	Distance Travelled [m]	How difficult did you find this task?
N		25	25	25	25	25
Normal Parameters[a,b]	Mean	.0716	82.80	.0565	2000.72	1.840
	Std. Deviation	.03172	57.410	.03938	161.482	.7461
Kolmogorov-Smirnov Z		.661	.482	.460	1.267	1.149
Asymp. Sig. (2-tailed)		.776	.975	.984	.081	.142

Table 8: One-Sample Kolmogorov-Smirnov Test

From the results shown in Table 8 we can say that our variable are all normally distributed (Sig. > 0.05) (Hinton et al.,p.30, 2004).

4.3 Time Pressure State

In this work, a difference is made between "time pressure state" and "time pressure felt". The first one is the status induced from the experimental design, i.e. the scenario the user was submitted to. The second one results from the answers given in the second questionnaire, when the user was asked about how much stress and time pressure he or she felt. It is shown in Chapter 4.4 that those two values are closely statistically related.

4.3.1 Visual comparison of variables for different TP States

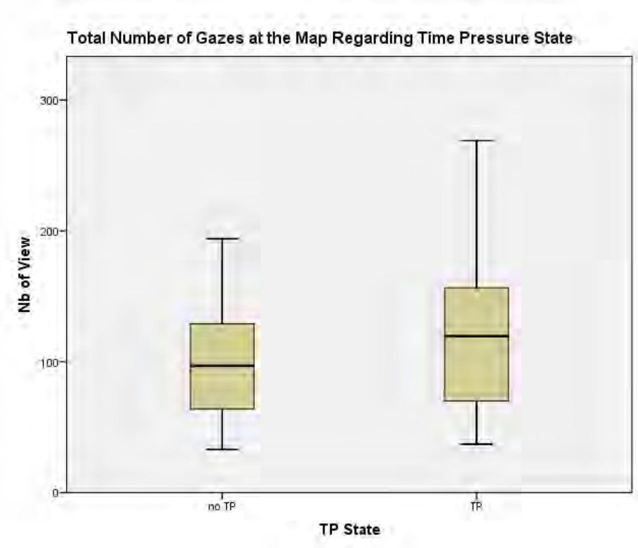

Illustration 14: Total number of gazes at the map regarding time pressure state. The range is wide and no difference appears.

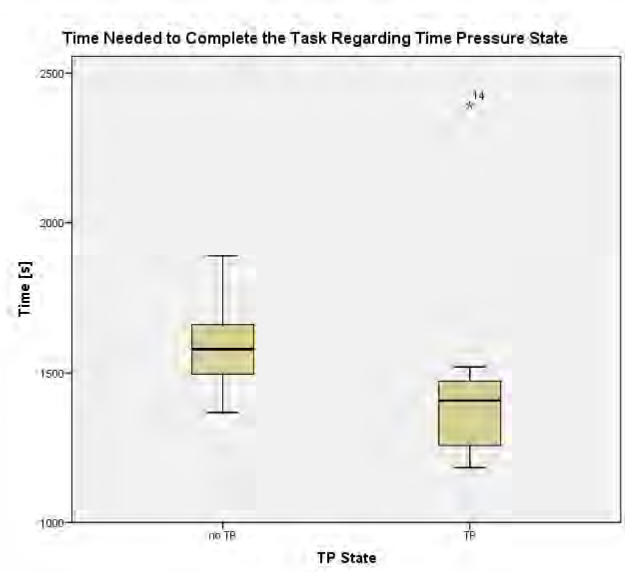

Illustration 15: Time needed to complete the task regarding time pressure state. The time seems shorter for participants under TP. 14 is a clear outlier.

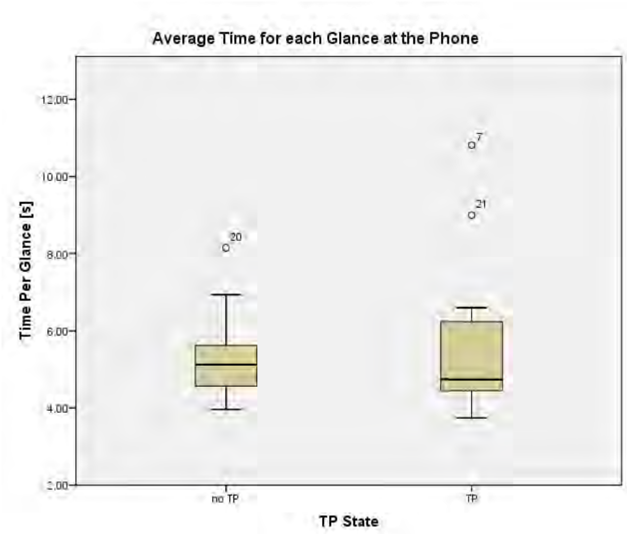

Illustration 16: Average time for each glance at the phone. No difference appears.

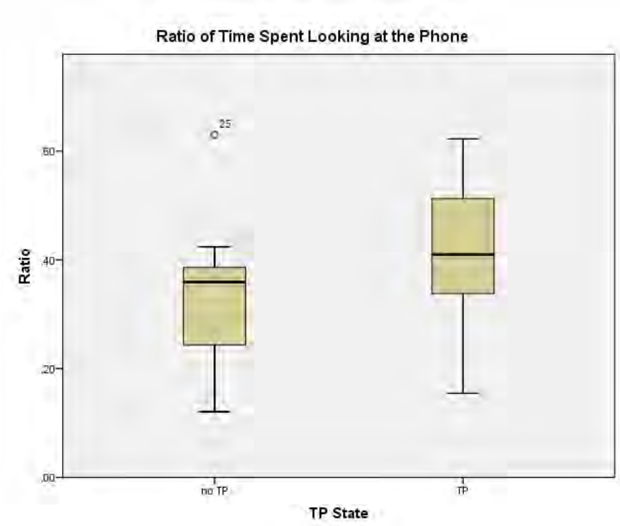

Illustration 17: Ratio of time spent looking at the phone. The ratio seems a bit higher for user under TP.

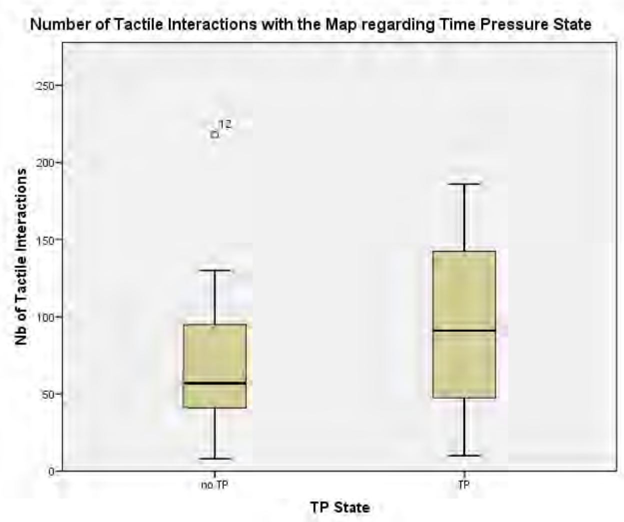

Illustration 18: Number of tactile interactions with the map regarding time pressure state. The range is wide, but the absolute number of interaction seems higher for user under TP.

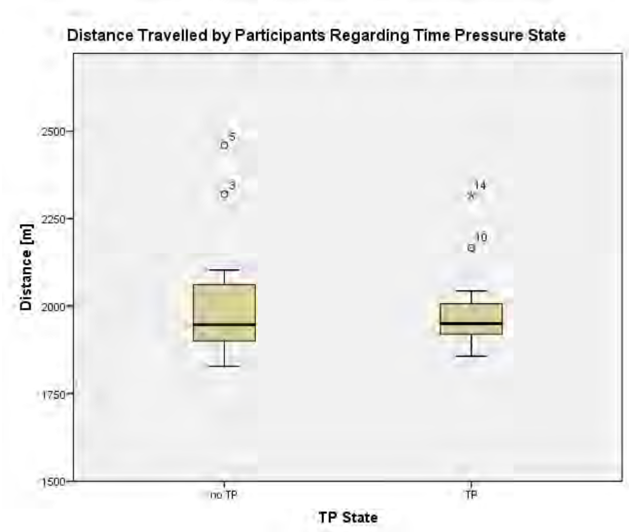

Illustration 19: Distance travelled by participants regarding time pressure. The two categories are very similar. 14 is an outlier towards more distance.

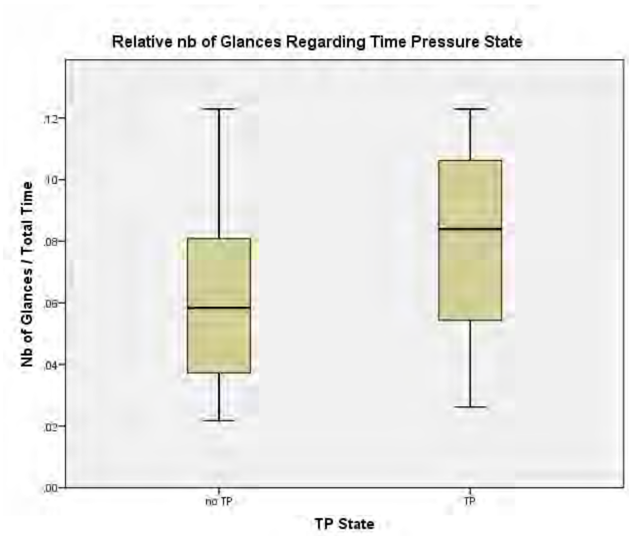

Illustration 20: Relative nb of glances regarding TP state. Very wide range and no clear difference.

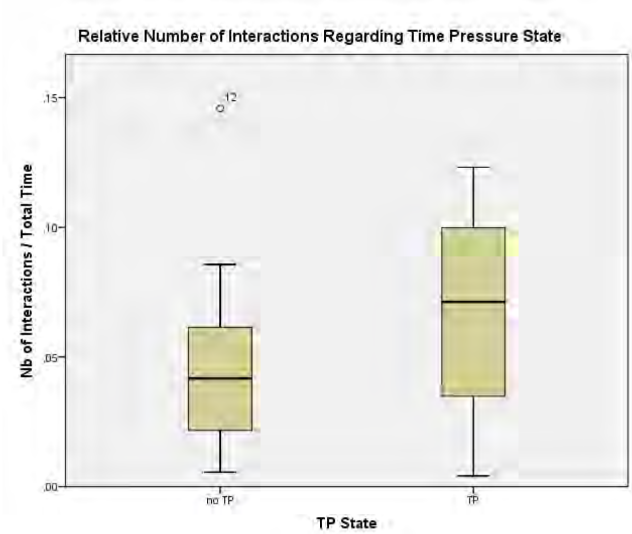

Illustration 21: Relative number of interactions regarding time pressure state. Slightly less interactions for the users without time pressure.

4.3.2 T-tests for the TP State

In order to estimate if the mean differences are significant, an independent T-test was conducted. This is to be used in addition to the graphs of the means.

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Nb of Glances at the Phone	.380	.544	.630	23	.535	14.686	23.299
Total Time Spent Looking [s]	.400	.533	.828	23	.416	83.058	100.259
Total Time [s]	.923	.347	-1.435	23	.165	-139.724	97.376
Time per Glance [s]	2.280	.145	.494	23	.626	.33739	.68363
Ratio of Time Spent Looking at the Phone	.001	.971	1.539	23	.137	.08010	.05204
Nb of Glances / Total Time	.214	.648	1.112	23	.278	.01405	.01264
Nb of Interactions	.014	.908	.763	23	.453	17.692	23.185
Nb of Interactions / Total Time	.183	.673	1.219	23	.235	.01903	.01561
Distance Travelled [m]	1.502	.233	-.272	23	.788	-17.946	65.929
How difficult did you find this task ?	.080	.780	1.619	23	.119	.4679	.2891

Table 9: T-tests for time pressure state.

From this tab we can see that the variance is to be considered as equal between the groups (Levene's test significance > 0.05). Therefore the valid results are on the first line of each test (equal variance assumed). However, there is no significant difference between any mean. We must conclude that time pressure induced to the user did not have any effect on the behaviour of the subject.

4.3.3 Errors in Itinerary and Time Pressure State

A quick examination of the data shows that no major error was committed by users under time pressure. To verify if this is significant and as these are two categorical (binary) data a Chi-square test was conducted to see if a relation could be found between the two variables.

The crosstabulation of these two variables is shown in Table 10. The result of the test found $X^2(1) = 6.2$, $p<0.05$ with a Cramer's V effect size of .488 which is rather large. From this it is possible to say that the time pressure probably have an effect on the major errors. This effect goes in the direction of a participant under time pressure is less likely to make a major error during the experiment.

		Major Error		Total
		No Major Error	Major Error	
TP State	no TP	8	5	13
	TP	13	0	13
Total		21	5	26

Table 10: Crosstabulation of major errors and time pressure state

4.4 Felt Time Pressure

As no relation was found between the induced time pressure state and the output variables, we decided to investigate the possibility that some participants were “time pressure resistant” or “time pressure hypersensitive” and therefore did not react as expected to the time pressure stimuli. The final questionnaire asked the participant how much time pressure and stress he or she felt. These questions were to be answered on a Likert scale (Likert, 1932).

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
TP Felt	5.247	.031	4.629	17.615	.000	1.5385	.3323

Table 11: T-test mean time pressure felt regarding time pressure state

Table 11 shows a T-test of the felt time pressure means regarding time pressure state. It can be said from it, with very high confidence (Sig. < 0.001), that the time pressure stimuli explains the time pressure felt by the participants.

However further investigations were done in this direction. A dichotomization of the felt time pressure data was done using the mean as separator and several plots were created to visually compare the means. Finally a t-test to quantitatively compare the means was conducted.

4.4.1 Visual Comparison of the Variable Regarding Time Pressure Felt

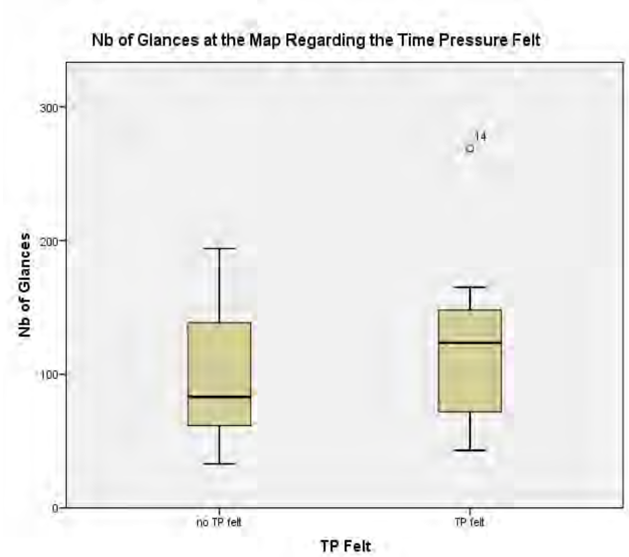

Illustration 22: Nb of gazes at the map regarding the time pressure felt. No clear difference appears.

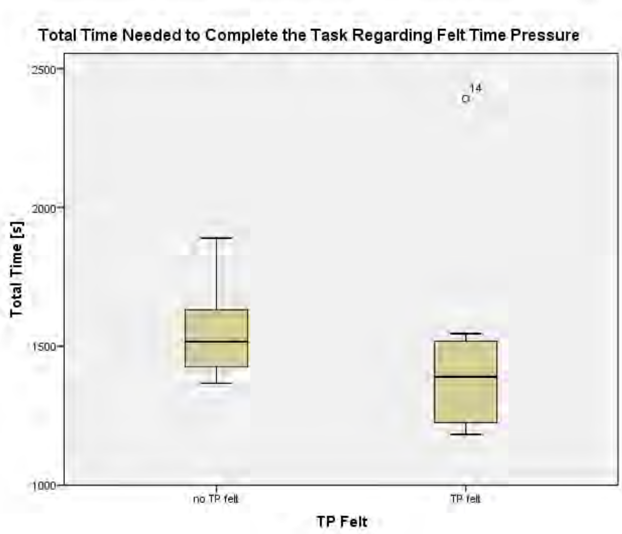

Illustration 23: Total time needed to complete the task regarding felt time pressure. Tendency for user without TP to need more time. 14 is an outlier.

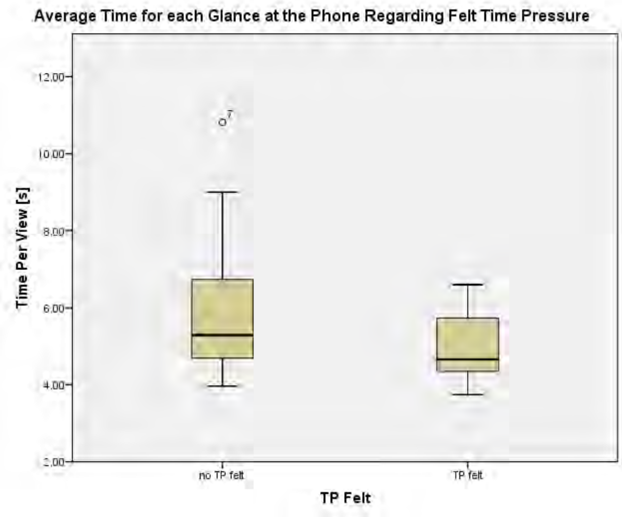

Illustration 24: Average time for each glance at the phone regarding felt time pressure. No obvious difference.

Illustration 25: Ratio of time spent looking at the screen. Wide range: from below 20% up to more than 60% of the time looking at the screen.

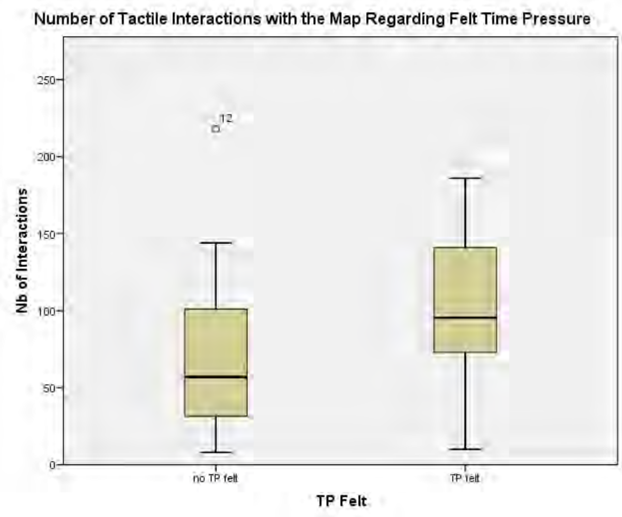

Illustration 26: Number of tactile interactions with the map regarding felt time pressure. Wide range, no clear difference.

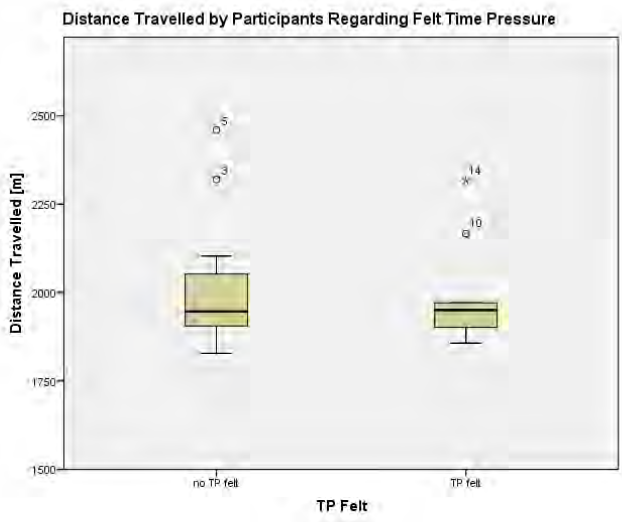

Illustration 27: Distance travelled by participants regarding felt time pressure. Rather narrow range with a few outliers among which 14.

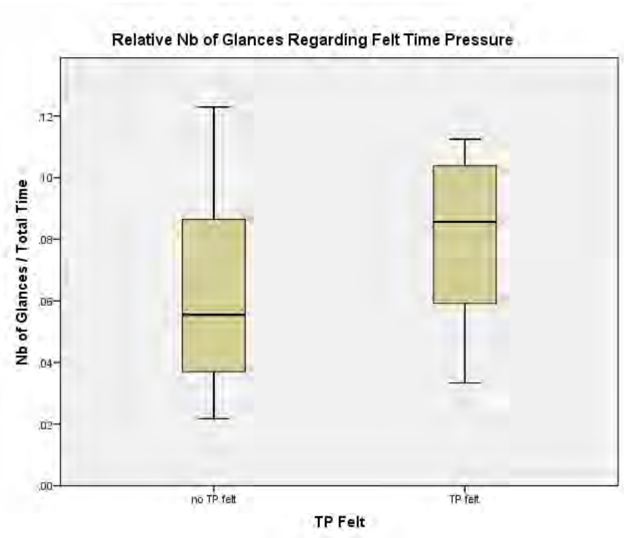

Illustration 28: Relative number of glances at the phone regarding felt time pressure. Again a large range and no obvious difference.

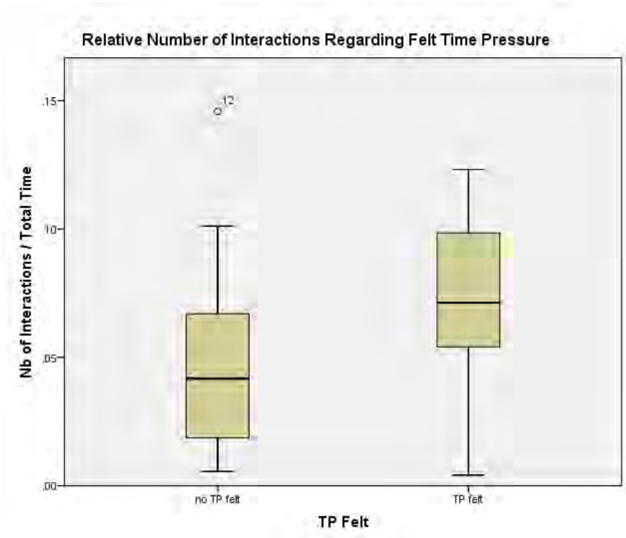

Illustration 29: Relative number of interactions with the map regarding felt time pressure. No clear tendency.

4.4.2 Felt Time Pressure T-tests

Even though there is no big visual difference between the two sets of graphs, T-tests were again conducted in order to quantify the difference between the two groups of time pressure. The results of these tests are to be found in the Table 12.

The Levene's test reveal that, at a confidence level of 95%, the variance is to be considered equal for all variables except the average time spent on each look at the screen. There is only one significant difference among the means. The question "How difficult did you find this task?" was asked in the same questionnaire as the questions about time pressure and stress. It is therefore likely that a user who answered that he felt a lot of time pressure also stated that he found the task difficult. However, it is interesting to note that time pressure and stress were associated with difficulty.

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Nb of Glances at the Phone	.084	.775	1.108	23	.279	25.867	23.350
Total Time Spent Looking [s]	.280	.602	.616	23	.544	63.400	102.914
Total Time [s]	1.818	.191	-.858	23	.400	-87.567	102.033
Time per Glance [s]	4.376	.048	-1.932	20.893	.067	-1.11338	.57639
Ratio of Time Spent Looking at the Phone	.220	.643	.911	23	.372	.04986	.05476
Nb of Glances / Total Time	1.245	.276	1.486	23	.151	.01877	.01263
Nb of Interactions	.081	.779	.841	23	.409	19.833	23.582
Nb of Interactions / Total Time	.002	.963	1.205	23	.241	.01919	.01593
Distance Travelled [m]	.482	.495	-.239	23	.813	-16.088	67.259
How difficult did you find this task ?	1.766	.197	3.845	23	.001	.9333	.2428

Table 12: T-tests for the felt time pressure.

More interesting, but not significant, is the relation between felt time pressure and time spent by glance at the screen. It seems that there is a tendency for users under time pressure to look by shorter glances at the screen. The implications of this finding will be analysed in the discussion.

4.4.3 Errors in itinerary and time pressure felt

A Chi square test was conducted to see if a relation could be found between the felt time pressure and the major error indicator. This Chi-square returned no significant relation between the two variables. To verify this with another test, a t-test was run to compare the mean of the continuous time pressure felt indicator regarding major error committed or not. No significance was found in this test neither.

A probable explanation of the difference between these results and the ones obtained with time pressure state is that the error did generate stress for users that were not under time pressure. On the other hand the users under time pressure that did not commit any error were probably satisfied and confident, therefore less vulnerable to time pressure.

4.5 Spatial ability and its Relations with the Variables

4.5.1 Paper Folding Test Results

The paper folding test was given to participants just after the background questionnaire. The score was calculated as the sum of correct answers minus a fifth of the sum of incorrect answers. The blank answers were not taken into account. The maximal possible score is 20 and the minimal possible score is -4.

N	**Valid**	26
	Missing	0
Mean		12.077
Median		12.500
Std. Deviation		3.9667
Minimum		.8
Maximum		20.0

Table 13: Descriptive statistics of the results of the paper folding test.

4.5.2 Visual Comparison of The Variable Regarding Spatial Ability

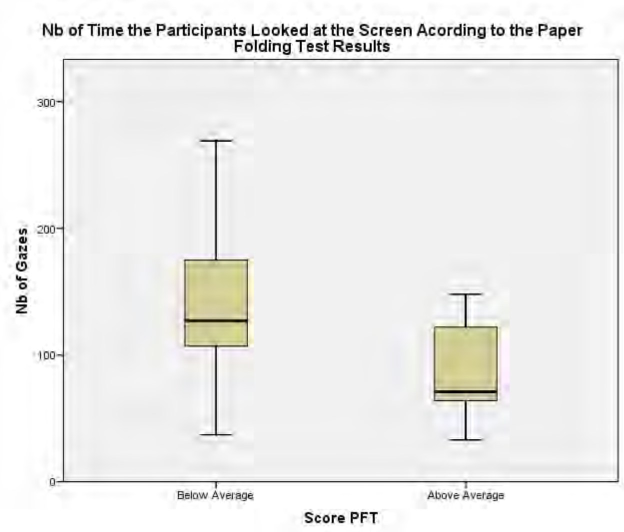

Illustration 30: Number of time the participants looked at the screen regarding spatial abilities. It seems that there is a tendency to look more often at the screen for the participants with a below average result at the PFT.

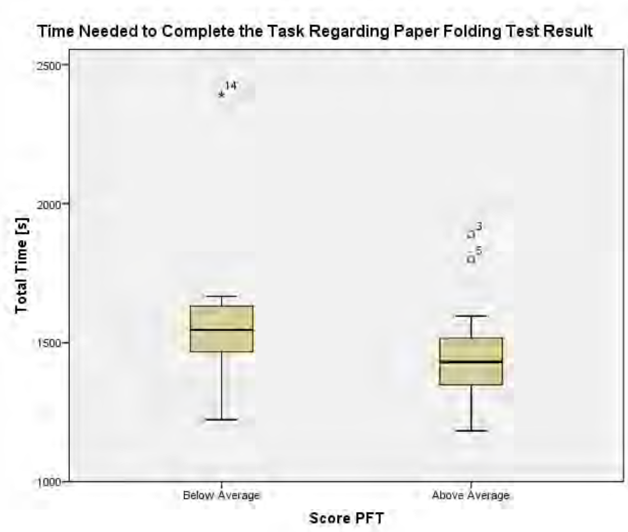

Illustration 31: Time needed to complete the task regarding paper folding test results. No clear difference appears. 14 is an outlier.

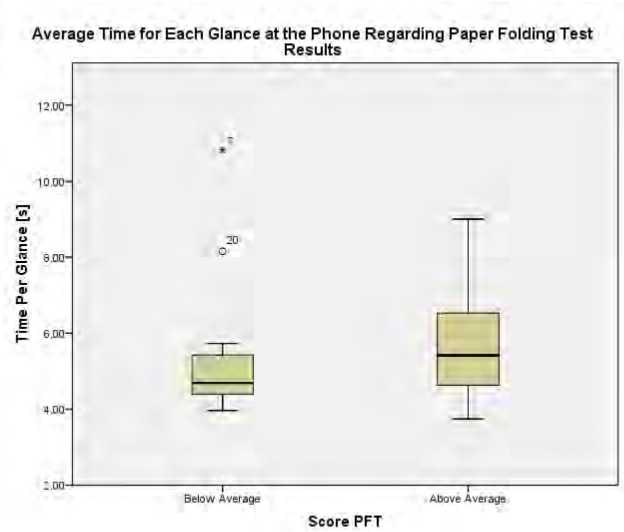

Illustration 32: Average time for each glance at the phone regarding PFT results. Smaller range for below average with two ouliers. It may be a bit lower too.

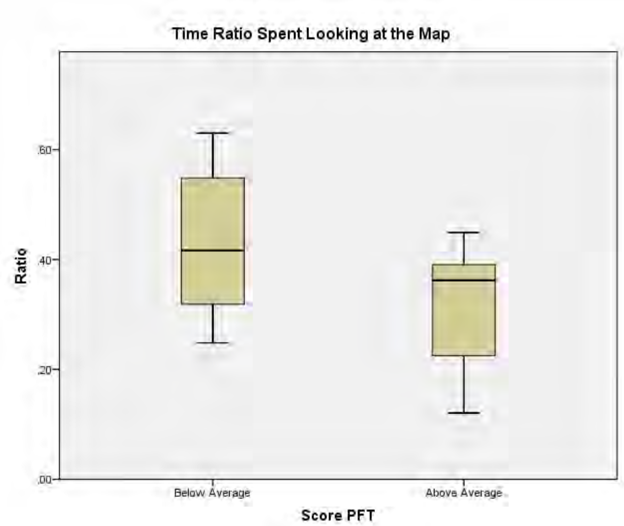

Illustration 33: Time ratio spent looking at the map. The ratio seems lower for participants with above average results at the PFT.

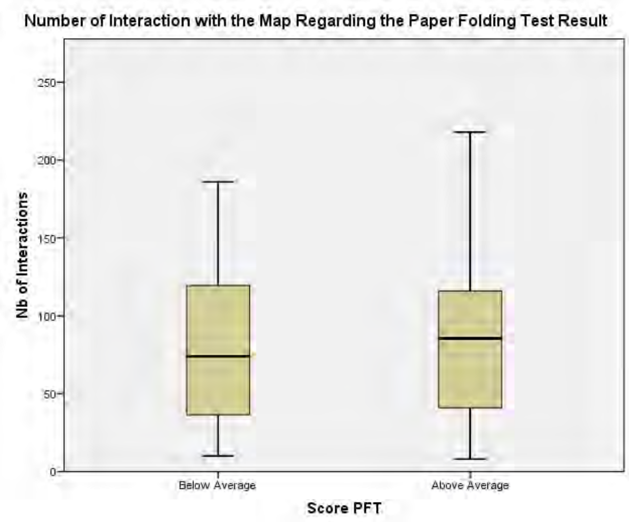

Illustration 34: Number of interactions with the map regarding spatial abilities. No difference appears.

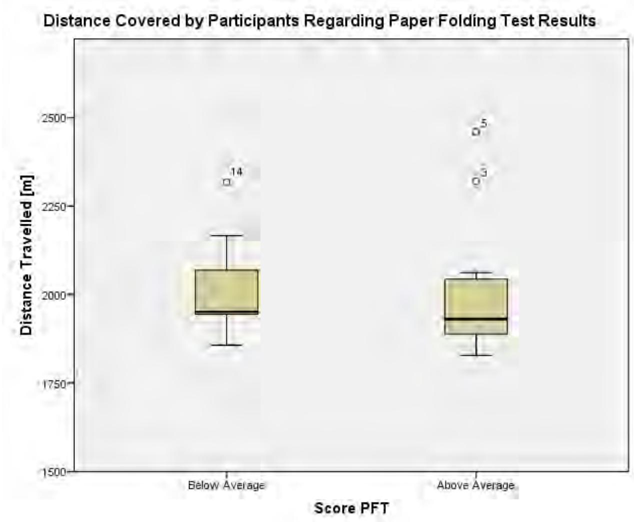

Illustration 35: Distance travelled by participants regarding spatial abilities. No difference appears.

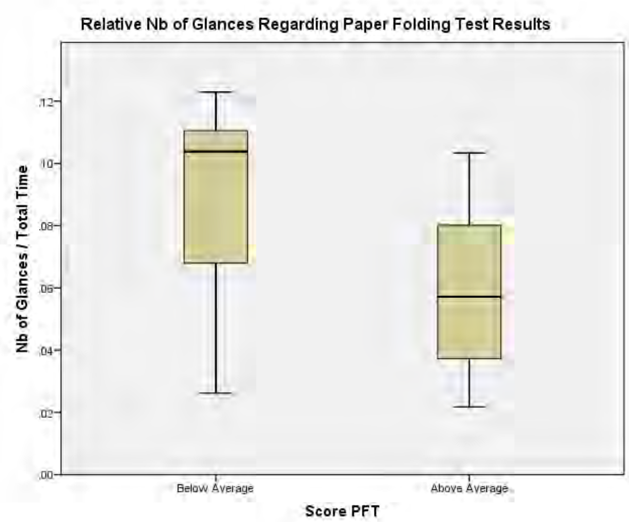

Illustration 36: Relative number of glances at the phone regarding spatial abilities. A bit lower ratio for the participants who scored higher at the PFT.

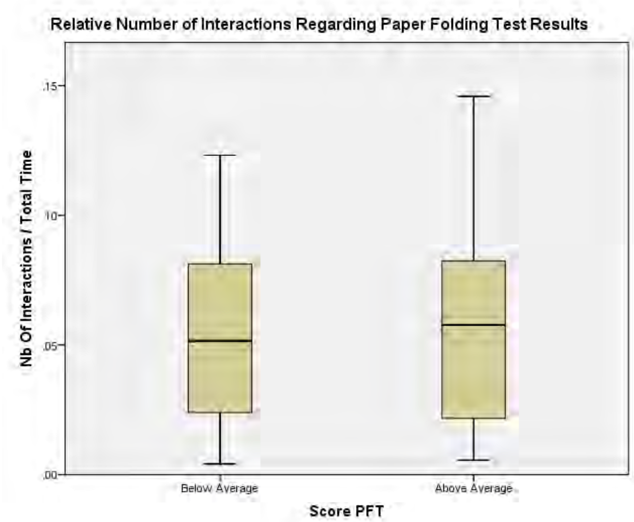

Illustration 37: Relative number of interactions regarding spatial abilities. No difference appears.

4.5.3 T-tests For The Spatial Ability

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Nb of Glances at the Phone	2.365	.138	-2.539	23	.018	-53.071	20.903
Total Time Spent Looking [s]	3.187	.087	-2.586	23	.017	-233.091	90.134
Total Time [s]	.150	.702	-1.356	23	.188	-133.50	98.439
Time per Glance [s]	1.060	.314	.093	23	.927	.06426	.69155
Ratio of Time Spent Looking at the Phone	1.517	.231	-2.355	23	.027	-.11630	.04938
Nb of Glances / Total Time	1.745	.199	-2.324	23	.029	-.02731	.01175
Nb of Interactions	.111	.742	.129	23	.898	3.052	23.620
Nb of Interactions / Total Time	.017	.898	.265	23	.793	.00429	.01618
Distance Travelled [m]	.400	.534	-.315	23	.755	-20.908	66.319
How difficult did you find this task?	1.061	.314	-.403	23	.691	-.1234	.3060

Table 14: T-tests for the paper folding test results.

We see in Table 14 that the Levene's test is always negative (Significance > 0.05). Therefore the assumption that the variance is equal between groups can be made. There is four significant differences between the means. The number of times that the user looked at the screen during the experiment is significantly higher for the user that had lower paper folding test results. The total time the users spent looking at the map is also higher for those who obtained a below average score at the paper folding test. The ratio of time spent looking at the map over the total time needed to complete the task is significantly higher for users with lower spatial abilities. Finally the relative number of glances (obtained from the total number of glances over the time needed to complete the task) is also higher for participants with lower spatial abilities. This implies that users with less spatial abilities needed more gazes at the map for a relative and absolute longer time spent looking at the map in order to be sure of their itinerary and be able to complete the task.

4.5.4 Major Errors and Spatial Ability

Similarly to the two previous time pressure variable, a test was done to see if a relation could be found between spatial ability and major errors occurrence. This was done by a t-test using the major error as separator for the means of the paper folding test results. No significant difference was found.

4.6 Other data analyses

4.6.1 Subjective difficulty

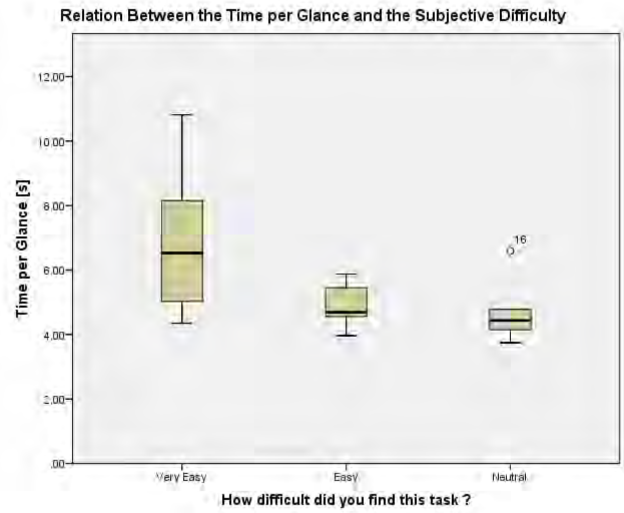

Illustration 38: Time per glance at the screen according to subjective difficulty of the task. It seems that the participants who found the task easier also used shorter glances.

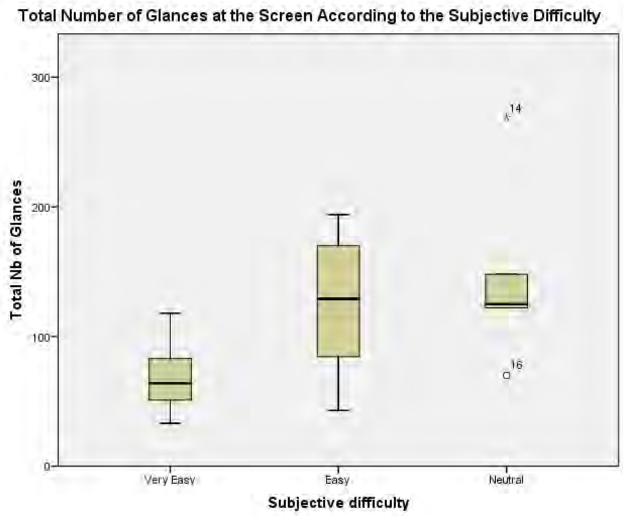

Illustration 39: Total number of glances at the screen regarding subjective difficulty. It seems that the participant who found the task easier looked less often at the phone.

For the average time per glance, an ANOVA revealed a significant effect of subjective difficulty $F(2,22) = 5.08$ $p<.05$ and Bonferroni post-hoc tests showed that there is a significant difference between the very easy and easy group. For the total number of glances at the screen during the experiment, an ANOVA showed a significant effect of the subjective difficulty $F(2,22) = 4.77$ $p<0.05$. Bonferroni post-hoc tests revealed a significant difference between the Very easy and the Neutral group.

4.6.2 Geogames

During the background questionnaire (available in appendixes at page 93), the participants were asked if they are frequent players of orienteering races or of geocaching. Orienteering race is a sport in which the participant receive a map presenting several waypoints to be visited in the shortest time as possible. Usually, the winner is the first participant to have visited all the points. This sport hence combines wayfinding and running abilities. Geocaching is a game in which the player follows instructions typically found on the internet to find a "treasure". The treasure has been hidden by another player and usually contains some trifles. The instructions are based on GPS locations and sometimes completed with enigmas.

Two users reported making regular deliveries for their side job, one with a bicycle and one with a truck. We thought that these activities could enter the same category as the two above. Hence the variable *Geogames* is the maximum score given to the question about orienteering race and geocaching. This score was manually increased for the two users cited above.

An analysis was conducted to verify if this variable influences the ability to read maps, orient oneself or deal with time pressure in these conditions. The population was dichotomized into the participants that never played any geogames and participants who answered at least once *rarely* or above. The significant or interesting results are shown in Table 15.

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
How difficult did you find this task ?	1.247	.276	-3.930	23	.001	-.9653	.2456
TP Felt	1.733	.201	-2.113	23	.046	-.9201	.4355
Distance Travelled [m]	3.898	.060	-1.963	23	.062	-124.856	63.610

Table 15: Selection of T-tests for the Geogames.

The participants who were used to maps and wayfinding clearly found this task easier based on their self rating scale of the final questionnaire. They also felt less time pressure even if with a smaller significance margin. Finally, it seems that there is a non-significant tendency for experienced users to use shorter routes.

4.6.3 Gender comparison

There is nearly no significant gender effect in my data. The only significant ($p = 0.045$) means difference was found in the *Geogames* variable. According to this dataset, men are more fond of orienteering races and geocaching plays than women.

4.7 Is User 14 An Outlier?

Illustrations 15, 19, 22, 23, 27, 31 and 39 shows that the user 14 is often very far from the others. This user was submitted to the time pressure stimuli, but took the longest time to complete the task. This participant had to stop and think for a while at nearly all intersection to be sure of the way to chose, even if it was straight ahead. This user also scored lowest in the paper folding test. In this particular case, the paper folding test result could maybe be linked to some cultural effect (Workman and Lee, 2004). It was therefore thought that the results were influenced by the participant's characteristics rather than by time pressure. An analysis was conducted without this user's data.

Compared to the results presented above, a new significant difference between the mean total time needed to complete the task regarding time pressure state ($p < 0.001$) and time pressure felt ($p < 0.01$) was found. The participants submitted to the time pressure stimuli took a shorter time to complete the task.

As this was the only difference in statistical results that appeared when user 14 was removed from the dataset it was decided to keep this participant's data in the study.

4.8 Skin conductance graphical analysis

In this chapter some analysis of the data obtained from the Smartband device are presented.

Data from the Smartband device is recorded at 10Hz. Among the various value available, of interest for this study is the Skin conductance level (SCL) and the time at which it was recorded. The SCL was first derived along time. Which in fact is done by subtracting its actual value with the value of the previous recording. This operation removes the tonic signal of the slow SCL drift and gives as result the skin conductance response (SCR). To withdraw irrelevant rapid fluctuations from the data a lowpass filter in the form of a smoothing was applied. This smoothing was based on the moving average technique. After a few trials and following recommendations by J.Papastefanou, the best results were obtained by ten iterations of a smoothing with a span of one hundred. This span means that the data situated up to five seconds before and after the point is taken into account in the average with equal weight[15]. Iterating the smoothing generate smoother data by flattening outliers. Finally a normalization of the data was done following the formula:

$$Phi = \frac{SCR}{(max(SCR) - min(SCR))} \cdot 100$$

In this work Phi(SCR) is referred to as SCR as it is only a normalization of this data, the information provided is the same.

Inaccuracy in this data can come from individual differences such as sensitivity to stress or the number of previous lab experiment done before. Previous appliance of skin cream is also likely to change the results (Figner and Murphy, 2010). The SCL increases linearly with the hour of the day (Hot et al., 1999), which might have had an effect on the results as the experiment was held from 8 am to 7 pm although it is unlikely as we used the SCR which is the first derivative of SCL.

To compare with this data, three other variables were prepared. First, the speed of the user regarding time was computed from the distance between two points of the GPS track over the time needed to cover it. The distance was calculated with the same script as in Chapter 4.1.5. Secondly, the number of interactions was computed from the number of time the participants touched the screen. More information about this variable can be found in

15 http://www.mathworks.ch/ch/help/curvefit/smooth.html [Last visited on 27 June 2013]

Chapter 4.1.4. To present this data on a time line, the interactions were grouped by ten seconds. Finally, the percentage of time the user spent looking at the map over ten seconds was calculated from data obtained by analysis of the video recording.

A graphic presentation of SCL, SCR, speed, ratio of time spent watching and interactions was created for each participant. In some cases, a peak of SCR was so much higher than the others that it was visually flattening the whole graph. To counter that a second plot was added with a zoom cutting out the peak. The most interesting cases are shown and commented here after a brief note on the effect of slope on SCR. This, as well as the drawing of corresponding graphs, was done by MATLAB scripts available in the appendix at page 102.

4.8.1 Skin conductance and slope

Before conducting the analysis we wanted to be sure that the slope did not influence the skin conductance. This could have happened as going uphill could generate a greater effort and hence more sweating. Effort sweating can not be differentiated by the Smartband from emotional sweating and therefore is likely to bring a bias in the outputs. For some users, the altitude at each of the points of their GPS track was computed using a digital elevation model in ArcMap. A graphical comparison was then done between this data and the skin conductance responses. An example is presented in Illustration 40 for user 16. This example, as well as the others examples not displayed here, show that no effect of the slope can be found in the SCR.

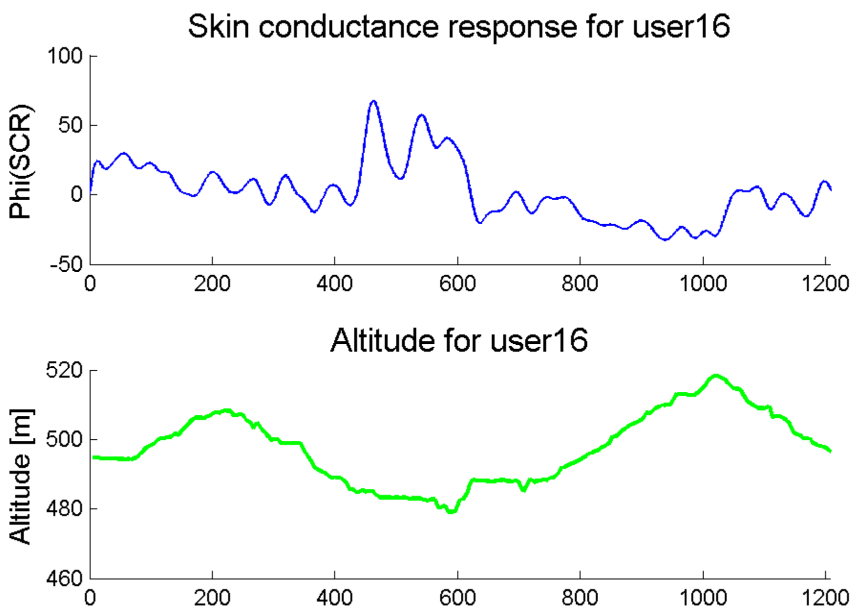

Illustration 40: Altitude and Skin conductance response of user 16

4.8.2 User19

User19 was under time pressure but first thought she might reach the target within the time limit easily. It becomes interesting because she realized a bit before the end that she was running out of time. It is confirmed by the video analysis because the participant said “Oh no, I won't make it!”. After the experiment, she said to the experimenter that she would have run in the last part if allowed. Time pressure increased considerably in the last quarter of the experiment. The moment when she noticed the problem is marked by a peak in the SCR at around 1200 seconds from the beginning (see Illustration 41). A change in the pattern of the SCR and SCL plots is visible before and after that peak. It seems that there is a bigger range between the maximum and minimum of the SCR and SCL data when time pressure is increased. This idea will be explored along with the number and frequency of peaks to quantify time pressure from the physiological data in Chapter 4.9.

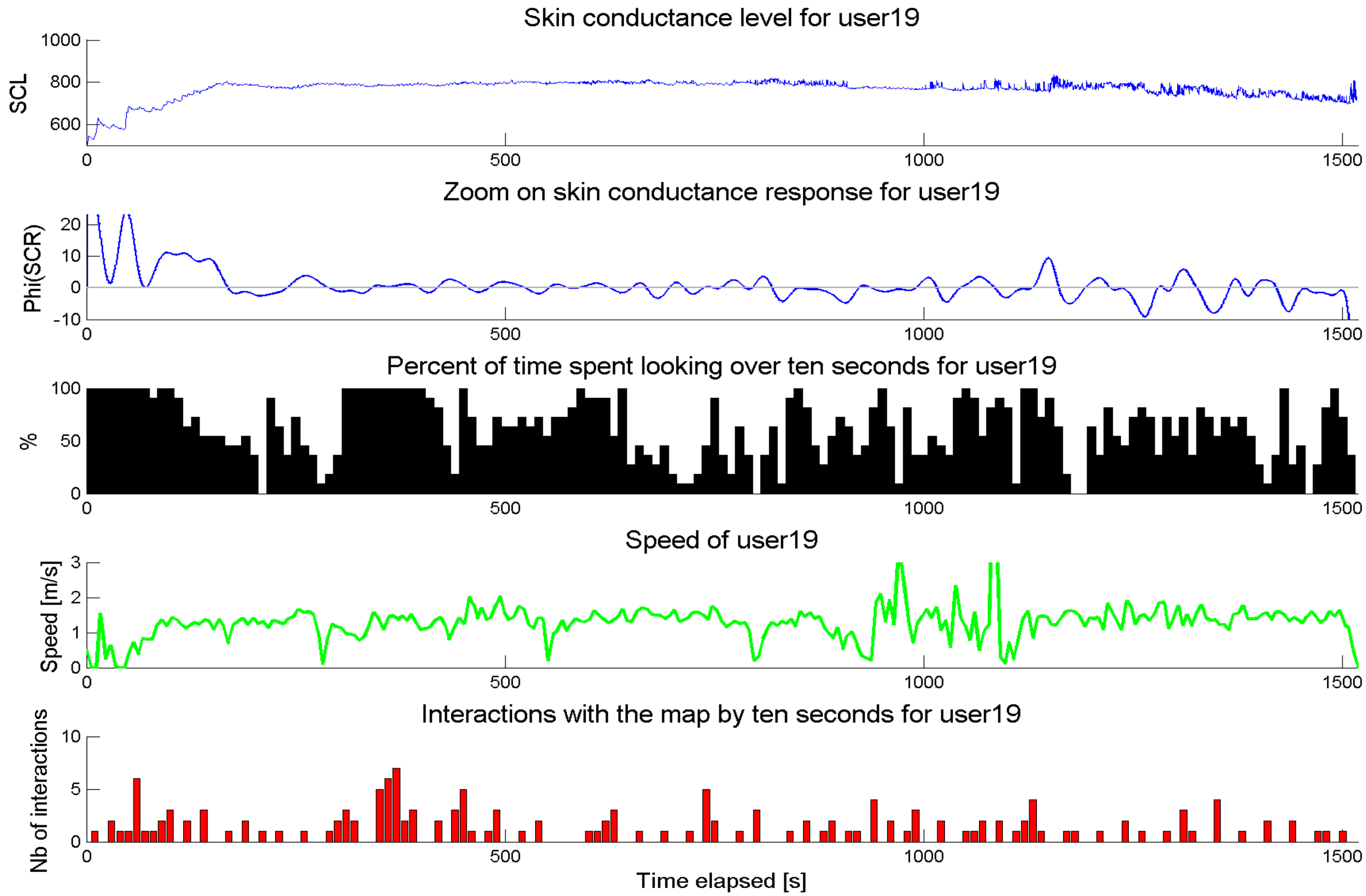

Illustration 41: Comparison of several data along time for User19

4.8.3 User5

The itinerary of participant number 5 was already presented in Chapter 4.1.5 (Illustrations 12 and 13) for having done the longest, and therefore less optimal, route. The data collected through the Smartband, the speed and the interactions with the map are presented in Illustration 43.

It is interesting to note, around 600 seconds after beginning, a peak of response in the skin conductance SCR), at the same moment the number of interactions increases as well as the SCL. This happened about a minute after the second point was encountered. By comparing this with the map shown in Illustration 42, one can see that at this moment the participant was starting to go back to the northernmost point, neglecting the closer and probably more optimal southernmost point. The most likely scenario is that the user had a doubt (SCR increase), checked the map (interactions increase) and realised the error (more SCR increase).

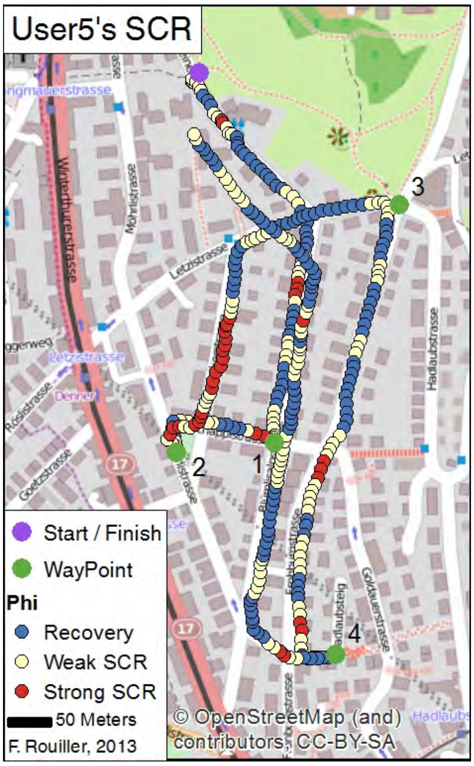

Illustration 42: Map of user5's SCR. Note the Strong SCR after waypoint 2. Probably resulting from the awareness of a suboptimal itinerary.

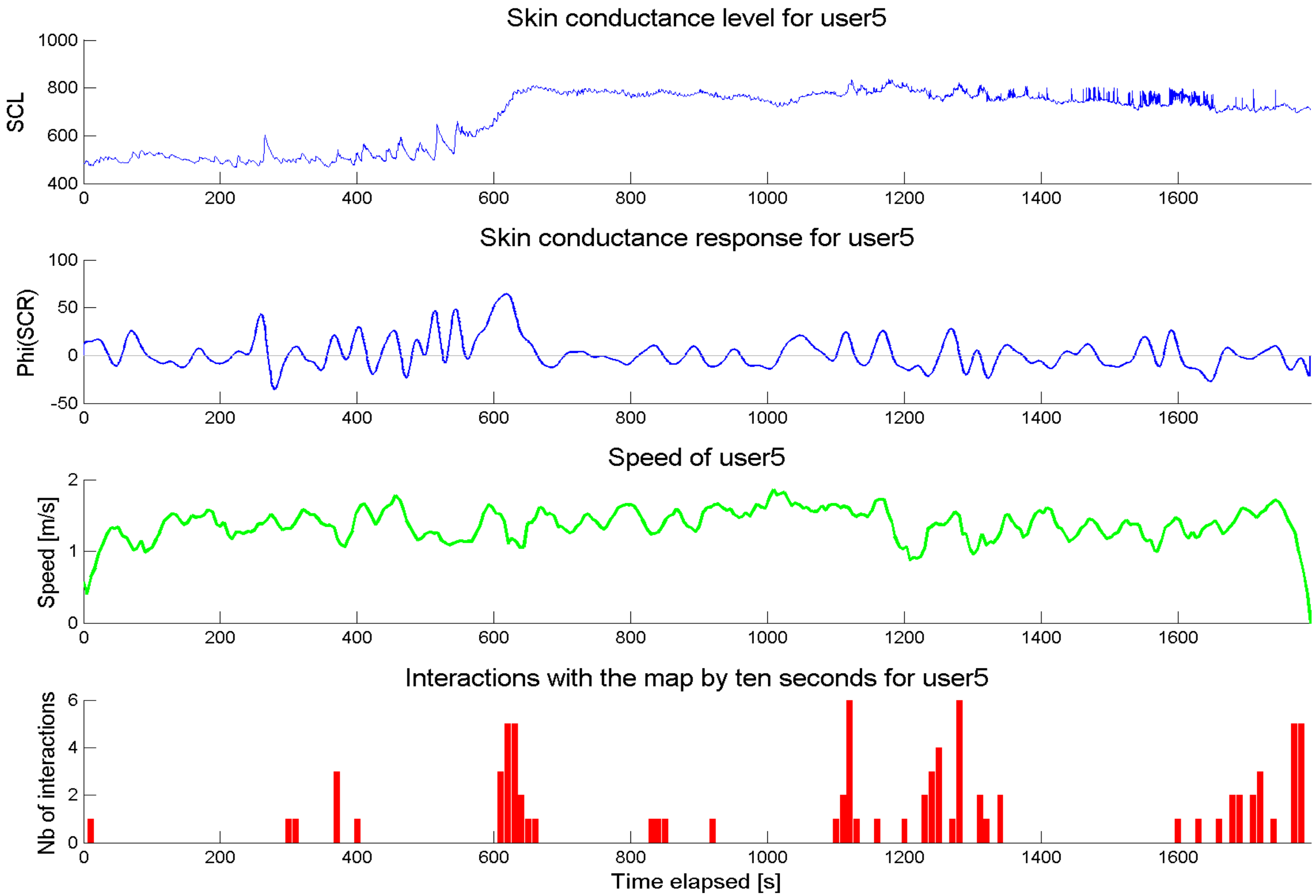

Illustration 43: Comparison of several data along time for User5.

4.8.4 User 20

The data obtained from user 20 is interesting because of its readability and the visual link that can be made between SCR, time spent looking at the phone, interactions and speed. In Illustration 44, around 250 seconds after the beginning of the experiment a peak in SCR can be seen (lines 1 and 2). This peaks occurs at a moment when the user was watching the map in average more than fifty percent of the time (line 3). The user was not only watching the map but also interacting with it, as can be seen in line 5. Finally line 4 shows that the participant stopped for a while at that point, at least in the beginning of the event. The maps presented in Illustrations 45 and 46 spatializes the data from line 1 and 3 of Illustration 44. It can be observed that the event presented above happened just at the first visited waypoint and lasted a bit after it. By analysing the corresponding video, one can see that the user tried to compare the name of the streets around to the map in order to locate him. This is somehow difficult because this point is located at the edge of a park and some street names indications are missing or too far to be read. The user said “I don't understand anything!”, then pointing a direction “I was coming from here, hm...”[16] and turned around several time before deciding correctly which way to follow. It was also at this point that he realised that the route was longer than he thought (“Wah! we're going far away!”[17]). Similarly, around 900 seconds, corresponding peaks can be found in the different data and are also related to difficulties to locate oneself just after the second waypoint.

Another interesting observation done with the data from this user is the small peak in SCR at 675 seconds following a period of recovery. At this point the user spotted a van similar to the one he uses for his holidays and showed it to the experimenter. This peak is hence a response to a positive stimuli and shows that such nuance is not easy to spot without complete recording of the experiment and in depth analysis of data coming from different sources.

16 In fact, the user said it in french: “Je comprends rien!”, “Je venais de là...”.
17 “Ouah! On va vachement loin!”

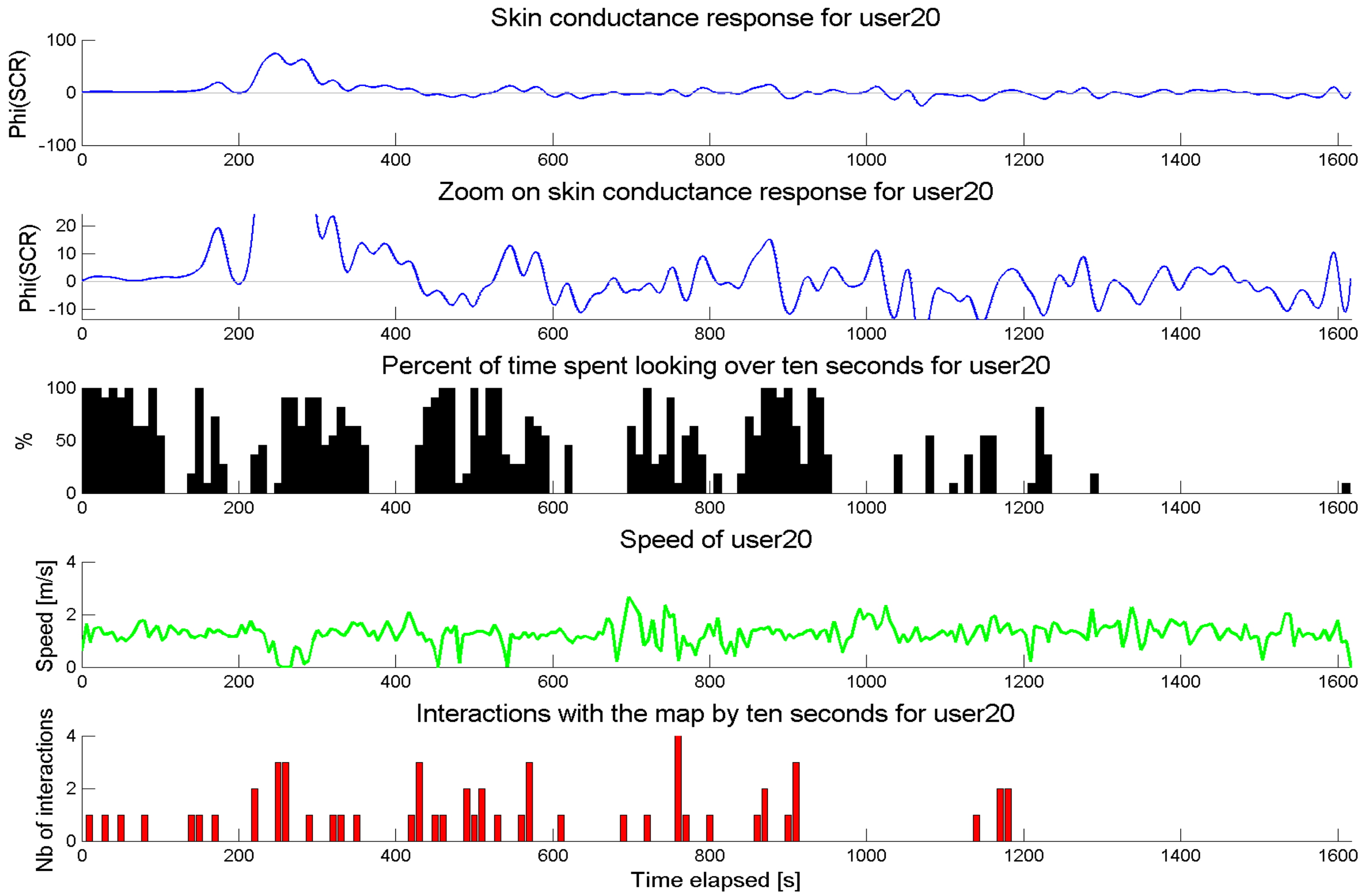

Illustration 44: Comparison of several data along time for User20.

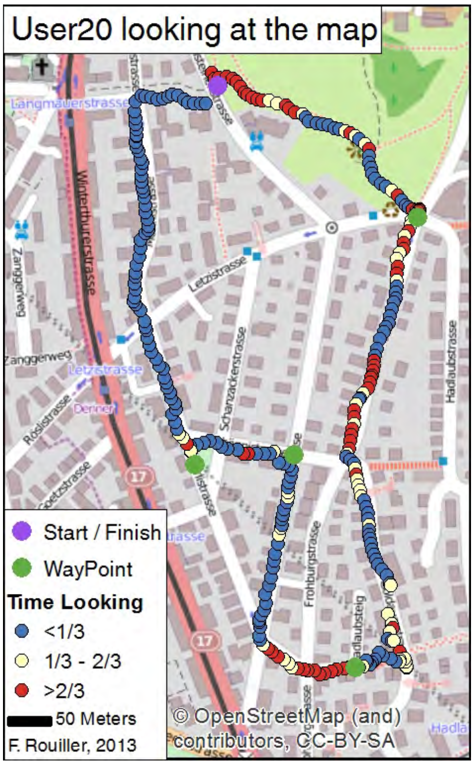

Illustration 45: Ratio of time spent looking at the map over ten seconds for user 20.

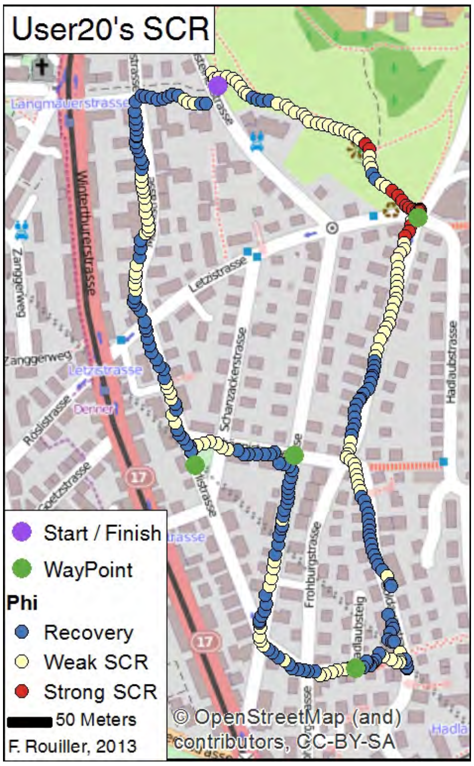

Illustration 46: Skin conductance response for user20.

4.8.5 User18

User18's data are shown in Illustration 47. A high number of interactions with the map and a lot of time spent watching at it, especially in the first half of the experiment, can be noticed. Some SCR peaks are identifiable at around 150, 250, 800, 1200 and close to the end of the experiment. Most of those peaks correspond to a waypoint (see Illustration 48 and 49) and are probably produced by the excitement of having reached one of the goals. It seems, on the other hand, that the wayfinding itself did not raise a lot of reactions for this user. They are also linked to a decrease in speed. In fact the user stopped at each point and planned the following itinerary from there. This user did not plan his itinerary in detail at the beginning but kept updating it after each of the waypoints. The number of interactions is very often of only one by ten seconds. The user chose a high level of zoom (i.e. showing only a little portion of the map), and hence had to pan the map very often to keep it focused on him.

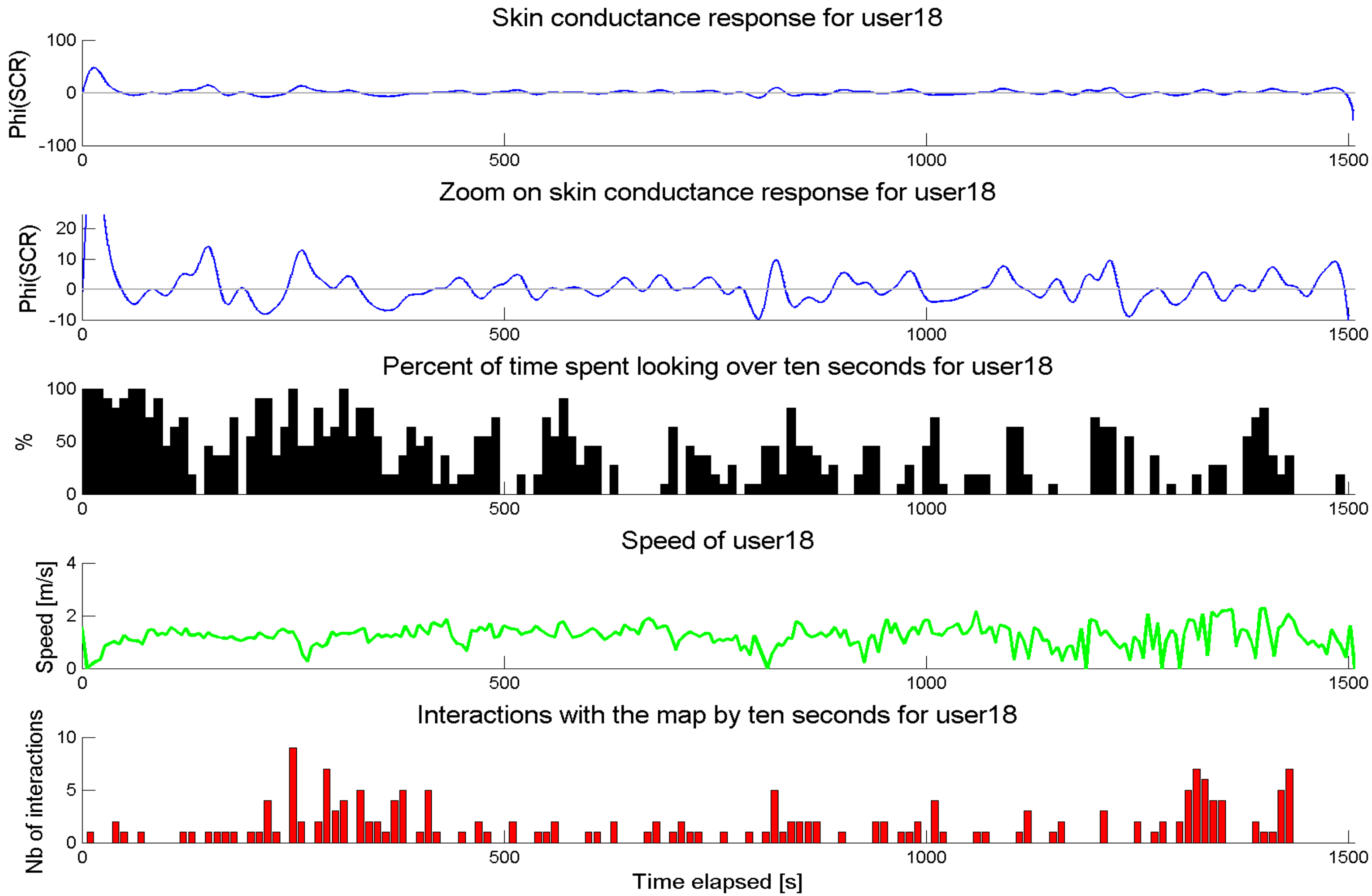

Illustration 47: Comparison of several data along time for User18

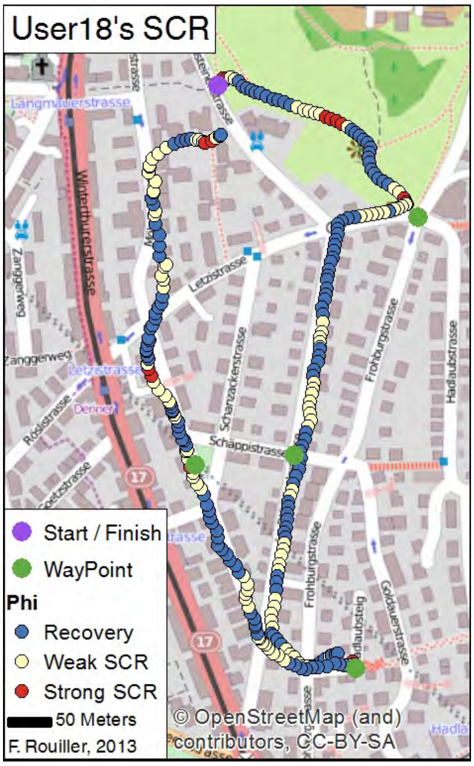

Illustration 48: User18's skin conductance response

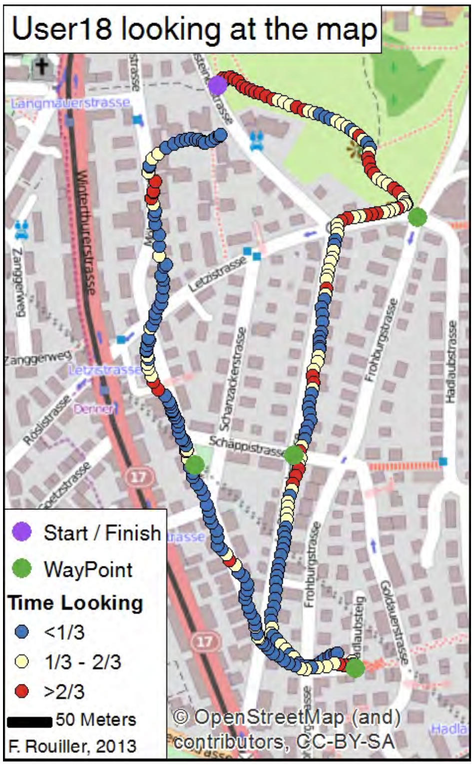

Illustration 49: Ratio of time spent looking at the map by ten seconds for user 18.

4.8.6 User2 and User26

User2 (Illustration 50) and user26 (Illustration 51) data are presented together as they illustrate two very different behaviours that can be found at various degrees in most of the participants. Participant26 is somehow similar to participant 18 presented in Chapter 4.8.5, but in a more exemplary way. The user26 watched the screen more than half of the time (56% of the time) during the experiment. He interacted 144 times with the map. On the other hand the user2 spent 22 percent of the time watching the phone's screen. He interacted 8 times with the map. User26 was under time pressure while user2 was not. This however is not determinant to explain the difference in map use as shown in Chapter 4.3. User2 scored 16 at the paper folding test, which is rather good. User26 scored 11.6 which is slightly below average. These observations are consistent with the statistics presented in Chapter 4.5. The users with lower spatial ability had to look at the map more often for an overall longer time spent looking. By comparing the SCR of the two users one can see that the data from user26 is rather flat except for a big peak at around 850 seconds. This peak is not linked with time pressure or danger of getting lost, but rather to the user walking uphill rather fast. The SCR plot of user2 is on the opposite very agitated even though he was not under time pressure.

Comparing the maps shown in Illustrations 52, 53, 54 and 55 clearly demonstrates the difference explained above. Note that user26 did the route in a counter-clockwise direction in the contrary to most of the participants. The SCR from user26 is very stable, staying weak or in recovery. The only exceptions are a bit after the beginning, the user did a mistake and went the wrong direction for a couple of meters and in the south-east of the route, the peak described above. For the participant2, the SCR varies much and more rapidly. It seems the user was reacting to a wide range of stimuli. Looking at Illustration 50, some SCR peaks can be related with higher ratio of time spent looking at the screen or drop in speed (e.g. at 400, 500, 700 and 1000 seconds). These peaks are probably linked with the experiment as they seem to be directly related with glances at the maps and stops which are signals of navigation issues. For other peaks, the relation is harder to establish (e.g. at 900 and 1100 seconds). On the map, some higher SCR are located close to the waypoints or the finish and are likely to have been provoked by the proximity of a target. Some others are not easily explained by the map analysis (e.g. the westernmost SCR peak) and no clue is to be found on the video recording nor in the notes of the experimenter concerning this experiment.

A possible explanation, which will be further developed in the discussion and in Chapter 4.9, is that the participants focusing on the map (such as user26) did in fact not pay attention to their surroundings. They followed the little blue arrow on the screen to see where they were and somehow forget a bit about their environment. Therefore they were much less sensible to external stimuli and relatively much more to internal stimuli such as physical effort.

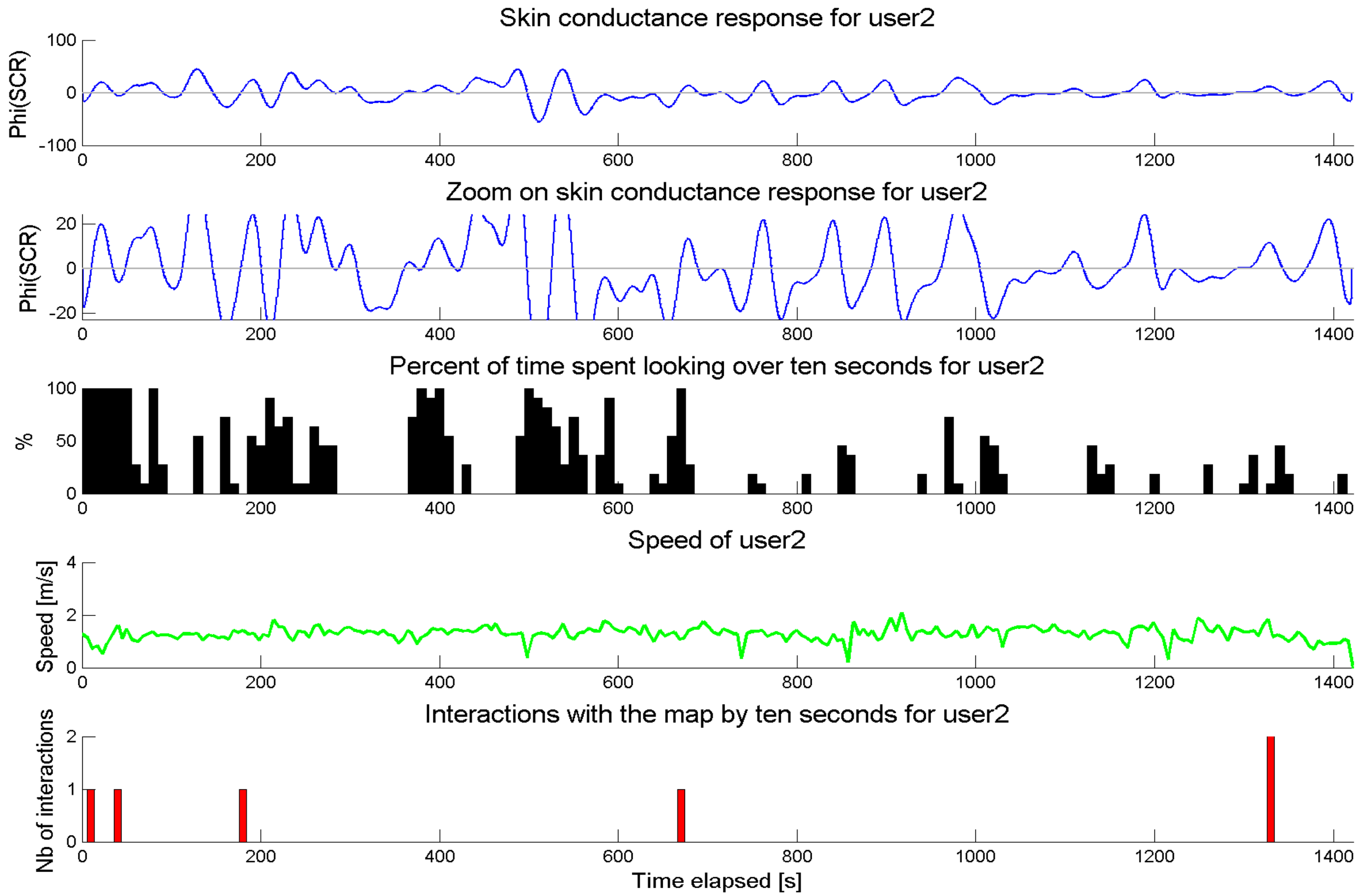

Illustration 50: Comparison of several data along time for User2

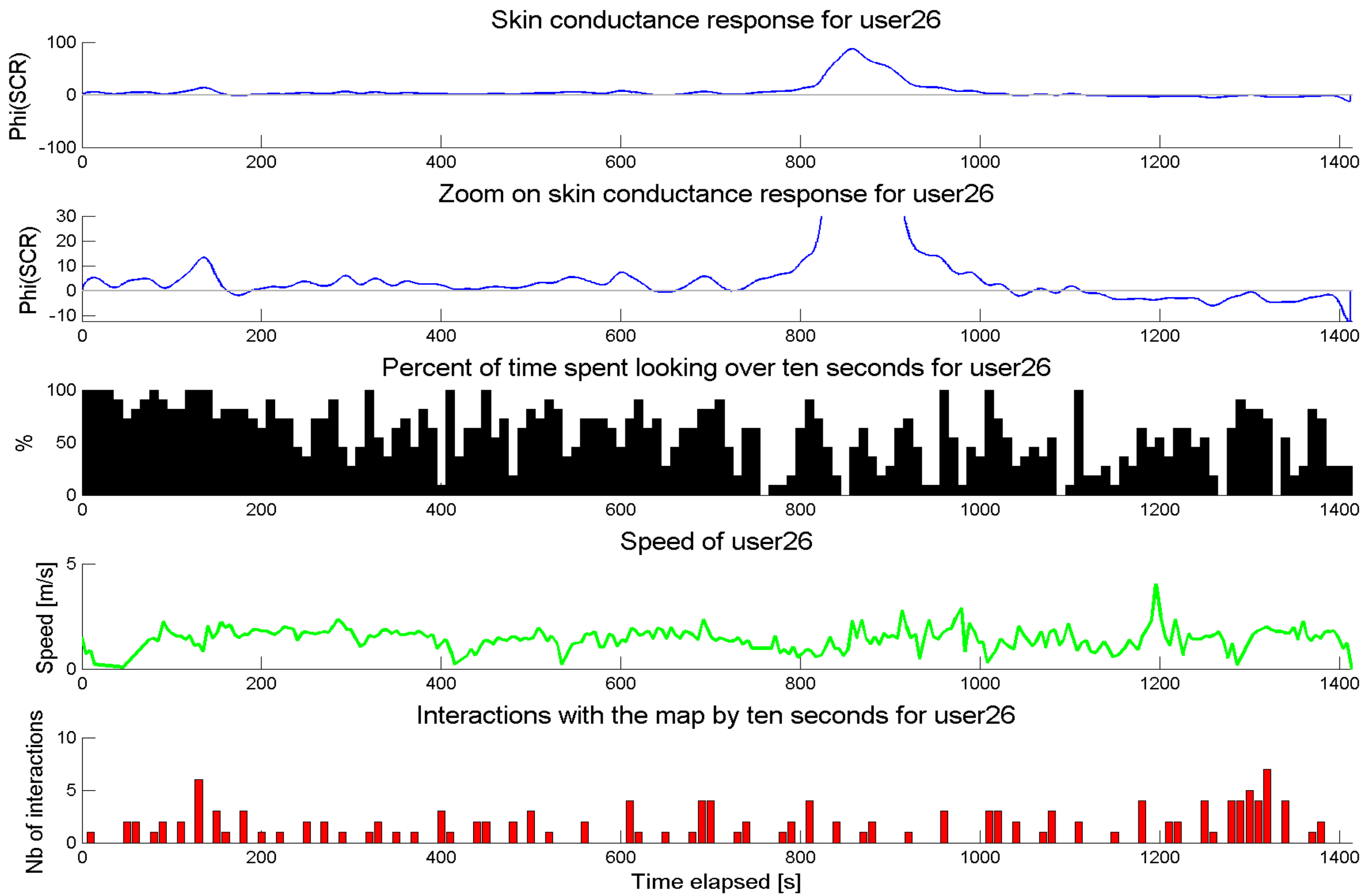

Illustration 51: Comparison of several data along time for User26

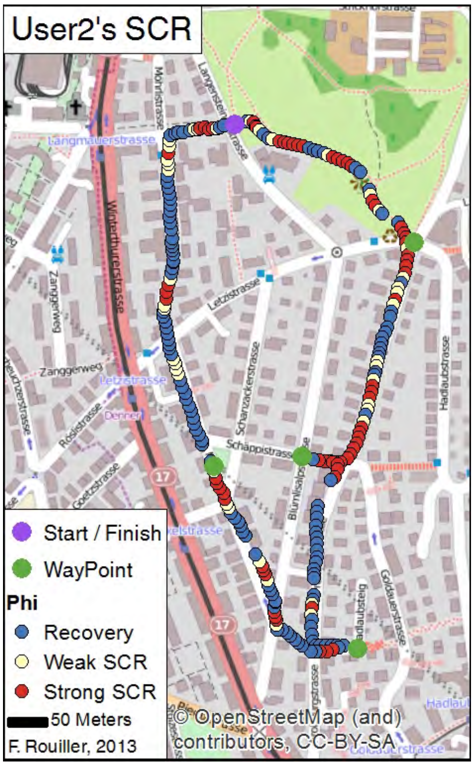

Illustration 52: Skin conductance response for user2

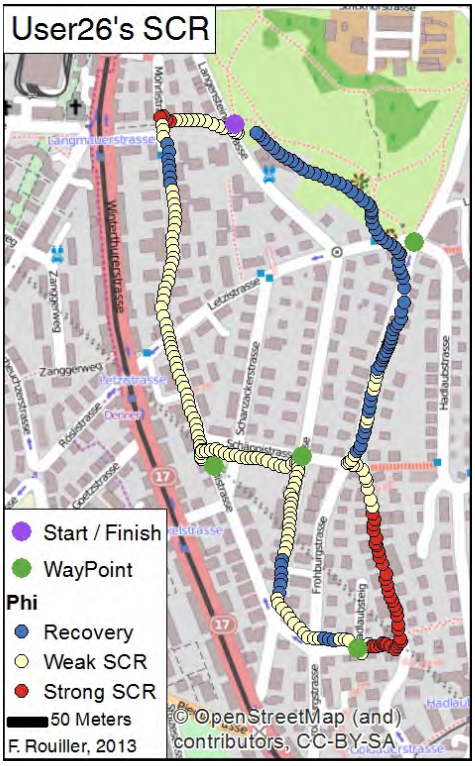

Illustration 53: Skin conductance response for user 26

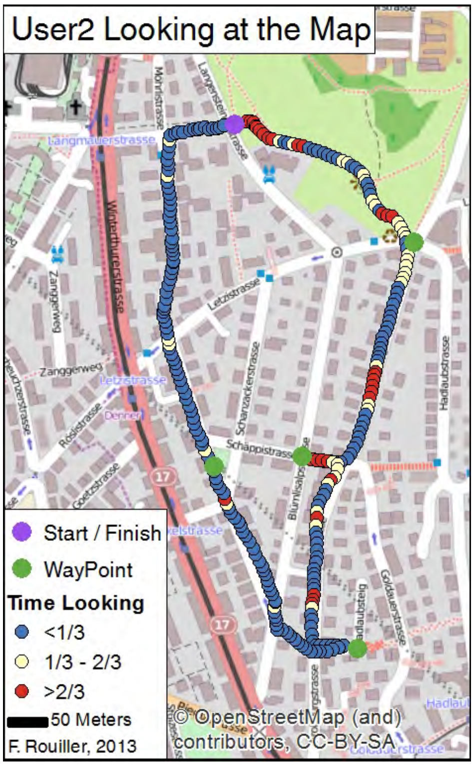

Illustration 54: Ratio of time spent looking at the map by ten seconds for user 2

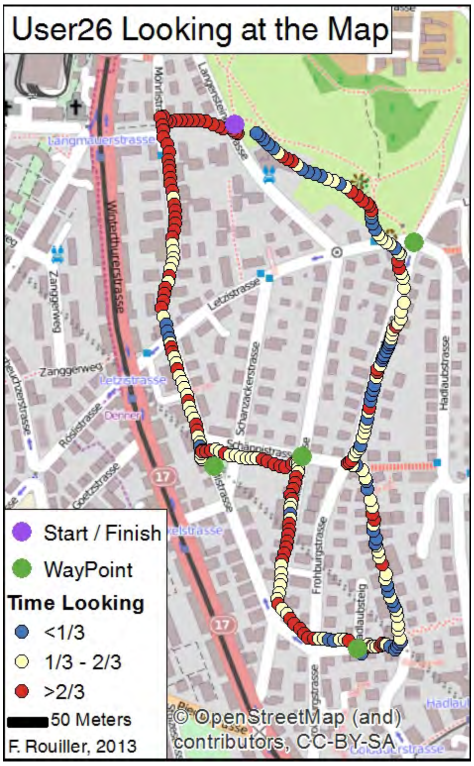

Illustration 55: Ratio of time spent looking at the map by ten seconds for user 26

4.9 Statistical relation between SCR and time pressure

To quantitatively assess the relation between physiological data and time pressure or other variables three approaches were tested. Unfortunately, none brought major significant results in the following statistical analysis.

The first approach is also the simplest. As most peaks in skin conductance data correspond to a response to a stimuli, it was thought that maybe a bigger number of peaks could indicate a higher level of time pressure. To verify that a MATLAB script was written to count the peaks. This process was repeated with 5 to 20 iterations of SCR smoothing with a span of 10 or 100. This allowed us to be sure that possible results were not hidden by a too strong or weak smoothing. The number of peaks was then standardized by unit of time.

The second approach is what Figner and Murphy (2010) explain to be a classical method. This was motivated as well by the finding showed in Chapter 4.8.2. In this chapter we saw that after a user felt a sudden increase in time pressure, her SCR had higher peaks and deeper minima. Hence it was thought that time pressure could induce a bigger range between extrema in comparison to SCR of a user at ease. Again a script was written in MATLAB, based on the latter one, to verify this supposition. MATLAB provides a useful function named *findpeaks* which returns the X and Y position of peaks in a data series. Minima can be found with the same function by simply providing the function with the inverse of the data.

Finally, according to Figner and Murphy (2010) again, the new trend in SCR analysis seems to be to analyse the area bounded by the curve. It is somehow similar to the second approach, except that the duration of the response is also taken into account. It is possible to obtain this by integrating the curve, but this process is not very easy as we do not have the equation of it. Moreover, typical integration subtracts the area below the curve to the area above it, but we want here the absolute area instead. Note that the SCR is the derivative of SCL, but knowing this is not enough to directly compute the area below the SCR curve. Figner and Murphy propose to sum all the absolute SCR values and to then normalize them with the time elapsed. This method was also implemented by a MATLAB script.

Once the SCR indicators presented above were computed, they were tested in several t-tests using time pressure state, time pressure felt and spatial ability as separator. Their correlations with the distance travelled, the ratio of time spent looking at the phone, the number of glances over the total time, the number of interactions over the total time and the results of the spatial ability test (for more information about these variables, please refer to Chapter 4.1) were calculated.

From this analysis, it comes out that our indicators are not seriously related to any of the other variables of our dataset. However, some isolated correlations can be found. The number of glances at the screen over the total time and the ratio of time spent looking at the phone are correlated with the number of peaks, especially when the smoothing is light (i.e.

when the number of peak is great because small maxima are not erased). These correlations are strong, between .431 and .648, with high degrees of confidence ($p = 0.001$ for the .648 correlation). A possible explanation to this is that each glance at the phone generated a small response. This response would be so small so that it would not be noticed in larger analysis and stronger smoothing.

The idea proposed at the end of Chapter 4.8.6 was that the user that focused more on the map than on the environment (i.e. the participants from which the ratio of time spent looking at the map is big, typically more than .5), had a flatter SCR. This could be due to the fact that, focusing on the map, they miss stimuli from the environments. To test this hypothesis, the correlations between the ratio of time spent looking at the map and our newly created indicators were computed. However, this did not return any significant outcome. Except the two correlations presented above, most of them are slightly negative (a negative correlation is in the sense of our hypothesis) and not significant.

The implications of these results will be commented further in the discussion.

4.10 Mobile Maps Alignment

The alignment requisite between the map and the environment (Klippel et al., 2006; Levine et al., 1984) is not always respected in mobile maps. Especially when the user is motionless and that the device is not able to determine the direction faced. This occurred at the beginning of the study when the map activity just started and the user did not move yet. The map was aligned north and the participant's position was represented by a point. Once the participant started moving, the point turned into an arrow that indicated the direction of travel. Interestingly the greatest number of errors occurred at the beginning of the study. Illustration 56 presents the itinerary of participant number 3. This participant planned a rather satisfying route somehow similar to the shortest solution presented in Illustration 29. Unfortunately, when starting to walk, the participant took the opposite direction for about two hundreds meters before realizing the mistake and turning around. This is probably a good illustration of the damage caused by a misalignment of a map with the environment.

Illustration 56: User3's itinerary. Note the error at the beginning.

4.11 Map versus Satellite

The application allowed the user to switch between map and satellite view and recorded this action. Illustration 57 shows the screen of the application if the satellite view is selected at the beginning of the experiment. Note the button at the upper right corner that allows the user to switch the view. This picture is to be compared with Illustration 4 on page 15 which shows the same area, but with the map view. Among our twenty-six participants, seven used the satellite view. Two of them used it for more than twenty-five percent of the time (26% and 35%, or around 300 and 500 seconds). Four used it for one to two percent of the time (15-30 seconds). One did use it only 4.5 seconds which probably corresponds to a misuse or a need to "push the button" to see what happens but not a real desire to use the satellite view. Especially because the downloading of the satellite data could take one or two seconds.

A t-test showed that the only significant difference between means regarding use of satellite is for the age. The participants that used the satellite view were older in average. However, there is probably a bias here because the two oldest participants (age more than 2 SD away from the mean) did both try the satellite view for a brief time (4.5 and 15 seconds). The mean ratio of total time spent looking at the screen is different between the participant that used the satellite view (M = .43, SE = .16) and those who did not (M = .35, SE = .12), although this difference is not significant (t(23) = 1.54, p = .138). The effect size is of .305 which is medium.

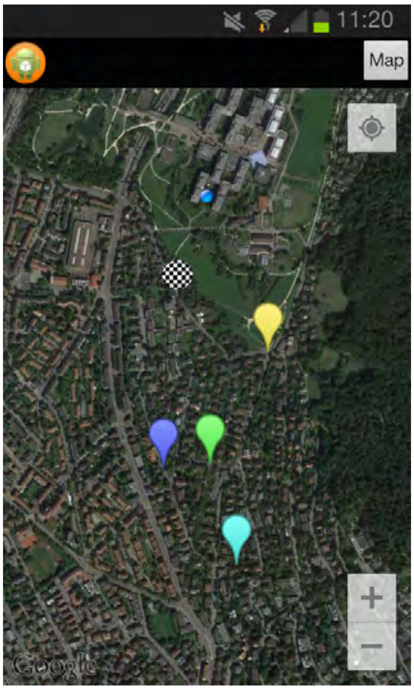

Illustration 57: The satellite view with the starting extent. The button to switch view is at the upper right corner.

5 Discussion

In this chapter we will answer to the research questions proposed in Chapter 1.1 with the help of the results obtained and presented in the previous chapter.

We will then discuss observations not directly related to the research questions that were made during this research, and try to highlight the results that deserve some attention.

Finally, we will discuss what worked well in this thesis and what could have been improved, especially in terms of the experimental design.

5.1 Answering the research questions

5.1.1 Does the itinerary choice change depending on time pressure?

The participants in this experiment had to visit four waypoints before coming back to their starting point. Participants could choose to navigate to the way points in any way they desired. Half of the twenty-six participants were put under time pressure. This question is answered by comparing the quality of the itinerary between the two groups.

Determining the quality of an itinerary is not trivial. For a car or a truck, it is clear that U-turns should be avoided and that the speed is different on a highway than in a residential neighbourhood. The gasoline consumption could be taken into account as well. For public transportation, an itinerary with less stops and modality changes might be preferred over more complex itineraries. However, on a relatively flat terrain and without dangerous streets, the quality of a pedestrian's itinerary can logically be measured only by its length. Turning around is not a problem for a pedestrian if it shortens the route, neither is making more turns or crossing streets (at least in a quiet neighbourhood such as the one of this experiment). In the literature similar solutions can be found in Ishikawa et al. (2008) or in Parush et al. (2007) who used the walked distance as an indicator of wayfinding behaviour.

Chapter 4.1.5 presents how the distance travelled was computed from the GPS data and provides some descriptive statistics. We then discovered in Chapters 4.3 and 4.4 that neither the time pressure state nor the time pressure felt by the participant could be held responsible for the changes in the distance travelled. Participants that were put under time pressure by the experimental design and participants that felt time pressure do not significantly use shorter or longer routes than the participants that were free of time pressure.

However results presented in Chapter 4.3.3 showed that participants under time pressure did not commit any major error. The *major error* variable is described in Chapter 4.1.6. This effect was assessed with a Chi-square test and found to be significant. This could be due to a known effect of time pressure, when not too strong, to increase performances (Andrews and Farris, 1972; Coeugnet, 2011; Wilkening and Fabrikant, 2011). On the other hand, this result is surprising as it is opposite to the conclusion of Srinivas et al. (2010) who found more error in the group under time pressure. This measurement was not replicated when using felt time pressure instead of the time pressure state. Possibly because the users who committed errors felt more stress in relation to the awareness of having done something wrong. On the other hand, participants who made no error felt confident in the quality of their performance and hence possibly reported less time pressure.

Time pressure seems not to influence the quality of an itinerary developed by a user, but might help to prevent major mistakes when following a route.

5.1.2 Does time pressure influence human-map interactions?

This question is first considered in terms of duration of usage of the map and answered by comparing the total time spent looking at the map as well as the ratio of time spent looking at the map over time. Furthermore, the analysis of the time by glance at the map, the absolute and relative number of glance at the map and the analysis of physiological data will complete this answer.

Secondly, this question will be answered by the analysis of the tactile interactions of the participants with the map and the usage of the satellite view.

The map usage duration data was collected by analysing the video recording of the experiment done by the inbuilt webcam of the smartphone used for the experiment. Detailed descriptions of these variables and how they were obtained are available in Chapters 4.1.1 and 4.1.3.

We saw in Chapter 4.4.2 that time pressure state is not related with the visual use of the map. Chapter 4.5.3 concluded by noticing a possible effect of felt time pressure on time spent by glance at the screen. It seems that the users that felt time pressure looked at the map by shorter, quicker, glances than users that did not feel time pressure.

Later on, in Chapter 4.8, we observed some plots of the variables. It seems that some peaks in SCR, especially when due to the user making a mistake or hesitating, are related with peaks in ratio of time spent looking at the screen. In other words, when a user is feeling an increase in stress, he or she will look more at the screen. Probably to verify the route or to decide which way to follow.

But the number of glance was not only related to difficult decision or danger of getting lost. In Chapter 4.8.6, we identified two different behaviours. Some subjects looked at the map very often and throughout the whole experiment. Others only a few times, mostly when a doubt emerges. On the one hand, some users were so concentrated on the phone they nearly bumped into objects (that were not on the map) along the way. On the other hand some participants put the mobile phone in their pocket during a large part of the experiment. We suggested that the subjects who spent the biggest ratio of time looking at the screen were also paying less attention to their surrounding, hence registering less physiological response.

Possibly, the users who kept watching at the screen had more difficulty to complete the task. This is partly confirmed by the results presented in Chapter 4.6.1, in that the users who had the shortest, but also most frequent glances at the screen also felt the task was harder. A user also told the experimenter at the end of the trial "In the beginning I was always watching the map, paying no attention to the environment. I found it difficult to orient myself. Then, I decided to watch the map less and I found it easier to decide which way to go". This user had big difficulties to find her way at the first intersection even if the correct path was straight ahead and most others solutions were unlikely (very steep grassy path). After this, she changed her strategy and never had trouble finding her way again.

A possible explanation for this can be found in studies that compare GPS devices and map based navigation (Münzer et al., 2006; Parush et al., 2007). Paying less attention to the environment is exactly what Parush et al. (2007) suspected to be responsible for a degradation of spatial knowledge acquisition: "*Over-reliance on the automated system may cause users to be "mindless" of the environment and not develop wayfinding and orientation skills nor acquire the spatial knowledge that maybe required when automation fails*". Subjects who watched the map only at critical points used it in the same manner as a paper *you are here* map. Hence applying classical wayfinding strategies between these points. On the other hand, the participants that continuously followed their progression on the map somehow substituted the environment by the map and themselves by the blue arrow. Hence being unable to correctly make a link between their surrounding and the virtual representation of it when needed.

The tactile interactions variables collection, treatment and descriptive statistics are presented in Chapter 4.1.4.

Concerning the tactile interactions with the map we found that, contrary to what was expected, the number of interactions variables are not correlated with the glances at the map variables. In other words, a user that interact a lot is not necessarily looking at the phone much.

Statistical analysis showed that neither the time pressure state, nor the time pressure felt had an influence on the number of interactions. The explanation is probably that the number of interactions is more dependent of the zoom level favoured by the user than to the time spent looking at the map or the time pressure. A high level of zoom requires the user to change the view a great number of times for each information request. On the opposite, a zoom level that allows the user to see the whole area could necessitate no intervention even if continuously watched.

In the physiological data analysis we saw that some peaks in the SCR time line can be related to peaks in the number of interactions. This is particularly the case when a wayfinding problem is the cause of the SCR increase. Hence we can say that when a problem about the way to follow occurs, the user needs more information to resolve it. The source of information being the map, the user access it by using its functionalities in order to clarify uncertainties.

Concerning the map and satellite view, we saw in Chapter 4.11 that very few participants used the satellite view. This data is hence to be taken with precaution. However, an interesting difference between the mean ratio of time spent looking at the map regarding use of satellite or not was observed. This difference was not significant, but if this effect was to be confirmed, for instance by an experiment with more participants, it could be interpreted in two ways. First, the users that liked to watch at the map more also liked to use the satellite. As they spent more time watching at the map, they had more time to use all its options. The second possibility is that the satellite is harder to understand and that collecting information from it takes more time. Therefore the participants that used the satellite spent more time watching the screen because they needed more time to make sense of the image. This later possibility is supported by existing literature suggesting that a higher level of detail might arm the usability of a map (Skarlatidou and Haklay, 2006; Wilkening and Fabrikant, 2011). This is coherent with the classical cartographic concept that a simple visualization is usually a good visualization (Bertin and Barbut, 1973).

5.2 Spatial Ability

The spatial ability was calculated from the results obtained at the paper folding test held in the first part of the experiment. Our paper folding test results, with a mean of 12.1 (or 12.5 if user 14 is removed from the dataset, see Chapter 4.7), are similar to those found in the literature. Ekstrom et al. (1976) found a mean of 13.8 for 46 college students and Workman and Lee (2004) a mean of 11.8 for 48 US students.

We compared the spatial ability with the other variables in Chapter 4.5. It was shown that, regardless of time pressure, user with lower spatial ability had to look more often at the map and for a longer overall time. This is very interesting as it is related to the results presented in Chapter 5.1.2. The participants with the lowest results in the paper folding test used the strategy of numerous and continuous short glances that is related with lower wayfinding results.

This is another evidence that spatial ability does play a significant role in wayfinding abilities and strategies.

5.3 Indicators of Time Pressure

We tried in Chapter 4.9 to find an indicator to summarize the physiological data into an indicator. This indicator could have facilitated greatly the analysis of the impact of time pressure as it would potentially have been more objective than our two other time pressure variables. However, no correlation have been found between our indicators and the time pressure. This could indicate two things: our indicators are wrong or the time pressure is in fact not generating observable differences in the physiological data.

The first hypothesis, “wrong indicators”, is backed with the fact that SCR are a succession of peaks and minima typically following stimuli. Somehow summing these maxima and minima is maybe not a good practice and each one should be analysed independently or along with other responses to the same stimuli.

On the other hand, this also could be an explanation to the second hypothesis, “no effect of TP on SCR”. Time pressure is a continuous state of the subject during the whole experiment. It is likely that peaks of time pressure (e.g. the precise moment when a participant realises he or she is late) are identifiable in the SCR curve. This was observed for example in user 19 (c.f. Chapter 4.8.2). However, the time pressure state itself can not be observed in the peaks and minima of SCR as its nature itself is in opposition to a short-term phasic analysis.

It could have been possible to search for similar indicators in the SCL, which is tonic and hence potentially more likely to contain information about a state. However, we saw that SCL is different for each person and even increases throughout the day. To compare SCL of a user during the experiment with his or her normal condition, it would be necessary to collect data during an extended period in which several states of mind are reached.

5.4 Others

5.4.1 Experience

We showed in Chapter 4.6.2 that the experienced users found the task easier and felt less time pressure. Other similar results were found earlier (Malinowski and Gillespie, 2001). However, the experienced users did not significantly perform better except for a non significant tendency to choose shorter routes, and in this sense our results are closer to those of Soh and Smith-Jackson (2004), who found no difference between experienced and novice participants.

We can therefore say it is important to record the background of the participants, even though their experience seems not to play a big role in the result. However, we had no participant that was an expert in map reading or wayfinding such as a professional orienteering racer.

5.4.2 Direction of Rotation

At the starting point, three streets could have rationally been taken (see Illustration 4 at page 15), the first one is a pedestrian, rather steep, path leading to the northernmost point and to a clockwise route. The second one is a road easily visible on the map. It is leading to a crossing very close to the northernmost point position. This crossing offers the choice to continue toward three points: the northernmost, the westernmost and the middle one. Most of the users who took that road continued towards the northernmost as well, probably because of its proximity. The last possibility, used only by a couple of users, was to take a downhill pedestrian path heading west and logically conducing to the westernmost point and a counter-clockwise itinerary.

Nearly all participants took one of the two first possibilities, globally heading south-south-east, at the beginning. This choice logically lead to a clockwise direction of rotation. It is maybe because the closest point to the starting location was the northernmost and that participants preferred to visit it first. Another potential explication is that people usually prefers to go southward (Brunyé et al., 2010). The two southernmost directions at the beginning were towards a clockwise direction of rotation.

5.5 Critical Analysis

I knew it is difficult to find participants for a study. In this case, mailing lists and a small presentation in an undergraduate class did bring less than a dozen of participants. Most of the participants were hence personal acquaintances. This was enough for this case, but a greater study would necessitate, of course, a motivation for the potential participants to sign in. Moreover, having acquaintances participating is an added risk of bias especially when time pressure is implied. The participants who know the experimenter might react differently, in both ways, to the stimuli. However, the experiment lasted for forty minutes to an hour, which is rather long for a voluntary work, and I was positively surprised by the number of people who managed to find some time to take part in it.

The application for the smartphone, despite a few bugs reported in Chapter 3.1.6, functioned well. It was possible to satisfactorily record all the data needed for the analysis in a format that proved usable. The application worked in a fluent manner so that the user could not make the difference, except for the layout, with classical mobile maps. Moreover, the application never crashed or had a bug so that the experiment must have been aborted or its data would have been unusable. Similarly the smartphone used never went out of battery, lost the GPS signal for a long time or showed any unexpected behaviour.

Time pressure was induced by setting a time limit for the experiment. It turned out that some participants realised only at the end that this time limit was constraining, even though it was really difficult to reach it. Some other users seemed not to care to much about this limit. Probably a more advanced scenario, some actor play from the experimenter, in depth role-play or a reward promise could have helped having more marked and continuous time pressure. However, this is difficult to achieve without bringing other forms of time pressure or stress. For instance, the hope of a reward might turn the time pressure into eustress, which is similar to what is experienced during a sport competition (Fevre et al., 2003).

The data collected from the Smartband is interesting and holds a lot of information. However, some lack of sources on how to interpret the data from this particular device led to a possible under-exploitation of its capacities. The Smartband produces ten channel of information, ranging from skin temperature to acceleration values, plus a time stamp channel. However, only the skin conductance and time stamp channels were taken into account in this experiment. This data can probably be used in such a way that very subtle observations can be done.

6 Conclusion and future work

This study presented the setting and the outcomes of a study in order to compare the users' behaviour towards mobile maps. The participants were separated in two groups, one under time pressure, the other not, hence defining a between-subject study design. The task of the experiment was to visit four waypoints presented on a mobile map and to come back to the starting point. The mobile map was presented on a smartphone which recorded several data during the trial. Beside the data recorded by the phone, physiological data was collected by a device called Smartband.

The produced data was statistically and qualitatively analysed in order to answer the research questions. In parallel, a spatial ability test was done and its results compared to the performance of the participants of the experiment. Aside from the answers to the research questions, some interesting results obtained from the same data were presented.

It was found that time pressure does not influence on the quality of an itinerary, but seems to prevent the user from getting lost. It was shown that the time pressure does not influence the time spent looking at the map, but could have an effect on the length of each glance at the map. The time pressure does not statistically have an effect on the number of interactions with the map, but some relations can be found in the physiological data between peaks in SCR and in interactions.

Participants with lower spatial ability had to look at the map longer and more often to complete the task. This was found to be in relation with another observation done in relation with the subject. It was noted that two strategies of information collection from the maps can be observed: numerous and continuous short glances or long and punctual glances. The first strategy seems to bring lower wayfinding performances. Interestingly, the users that scored low on the spatial ability test appeared to prefer the first strategy.

Physiological data proved very interesting and complementary with the other sources. Its analysis however needs to be focused on a stimulus and its associated response. In this case time pressure is not identifiable as a punctual stimuli but is rather an overall state during experiment. We tried to identify indicators based on physiological data to quantify time pressure, but we were unable to statistically prove their relation with time pressure. Moreover, some example showed us that the skin conductance can also be influenced by external stimuli and therefore becoming confusing.

As a side conclusion of this study, it can be noted that data from several sources, including a Smartband, a smartphone and two questionnaires can be combined in order to obtain satisfying results. The rise of smartphones technology and their availability was briefly presented in the introduction. This study proves that smartphones can be successfully used in geographical and related studies. Their ease of programming and the increasingly high quality of their inbuilt equipments such as cameras and GPS make them very interesting to collect data in a scientific purpose.

6.1 Future Work

This study could be completed by other experiments or the data could be analysed with other tools. We present here some trails and ideas that were not implemented in this case but could potentially lead to meaningful results.

6.1.1 Interpolation of the GPS track points

Interpolation is the computation of values on a continuous surface based on measurement points. The idea here was to identify areas where participants had in average a higher level of SCR. The GPS track points with the corresponding SCR were used as the input points. The interpolation method used was an inverse distance weight (IDW) because it is important that closer points have more influence on the local value. On the opposite, it was not necessary that the calculated surface goes through every data point as would a spline do. Moreover the density of points is high as the area is limited to the roads and IDW deals better than splines with high density of input points. After a few trials, the weight was setted to one and the maximum distance for a point to be taken into account was fifteen meters. Illustration 58 shows the result of this trial.

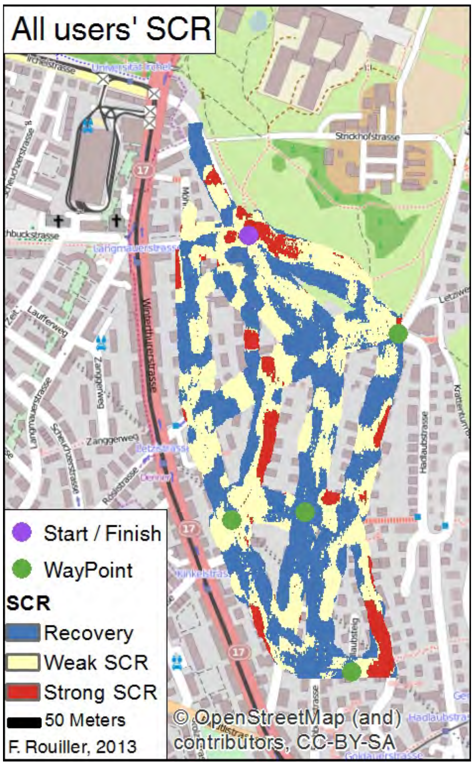

Illustration 58: Interpolation of the SCR at GPS track points for all users.

At first glance it seems that some zones are identifiable, such as the bottom-right red area. The problem is that, as the user were free to chose their itinerary, some routes were used much less than others. The bottom-right area was in fact visited by only two users, from which one had a peak of SCR at this location which makes it appears very stressful. The other locations are pulled towards a medium level of SCR because of its phasic propriety. A peak is generally directly followed by a minima, which nullify the average over a few meters distance. This effect could be controlled if all the users were using the same itinerary in the same direction because the peaks would then occurs probably at the same location. Here, if a user arrives to a stressful point from the opposite direction as another participant it is likely that their SCR will neutralize each other.

However, on this map a few features are worth noticing. The starting point is located in a red zone, which makes sense as the beginning of the experiment was usually a stressful part of it. Three of the four waypoints are located in weak SCR zones, which might indicate a global increase in SCR in the proximity of these points.

In future works, especially if the number of participant is greater, it would be interesting to isolate identical itineraries. This could then be used to identify zones of particular signification for the majority of the subjects.

6.1.2 Isolating Parts of Itineraries and Cluster Analysis

Isolating parts of itineraries could be done for example by identifying all the users that used a particular stretch of road in a specific direction. Each user's itinerary could then be divided into a sequence of stretches. Some tools exist that permit the analysis of such sequences (Fabrikant et al., 2008). The power of such tools is their capacity to identify similarities between sequences. The users that took nearly identical itineraries, or part of itineraries, are classified into clusters. A pattern could then be searched in these clusters based on the other variables of the study. This method could provide new insights about time pressure being linked to a particular pattern of stretches. For example, it would be difficult to note with classical map observation if all user under time pressure took a similar but not identical itinerary. On the contrary, it would probably be more visible with this clustering technique (Çöltekin et al., 2010). It could also facilitate the separate treatment in the analysis of users that took eccentric itineraries and to measure the difference between itineraries.

6.1.3 Strategies of Mobile Map Usage

It appears in this work that two different strategies are applied by the user to gather information from the map and apply it to subsequent wayfinding. One of these strategies seems to provide better wayfinding performances. A link was also found between these strategies and the spatial ability test results. As this was not the central question of the master thesis, the data collection system was not designed to investigate in this direction. However, it is probably an interesting observation that is comparable to other works in the domain (Münzer et al., 2006; Parush et al., 2007). To keep investigating on this subject could bring new insights on the cognitive processes involved in mobile map navigation. Further research in the direction of overconfidence in automation adapted to GPS navigation might probably be relevant to deepen this observation. The link with spatial ability could be clarified by the use of more tests such as those used by Liben (2010). It could be interesting to analyse the efficiency of both strategies for one subject (within-subject design) as well as investigating what factors determines user's preference of one strategy over the other.

6.2 Closing Personal Word

This work brought me to synthesize many skills learned throughout my geographical studies. From the first year's statistical classes to recent geovisualization courses, many subjects proved useful and appropriate to achieve such a work. I also had to enhance my programming abilities to develop the Android mobile phone application.

In the university or in other institutions, I had already done most of the steps of a study but separately, analysing someone else's data or producing data that another researcher would later use. Accomplishing all the parts of the study was a very satisfying experience.

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Appendix

A - Code of the application

Map.java, presented here, is the code for the map activity. The three other classes that complete this code are less specialised and hence not worth showing here. The XML code for the layout as well as the android manifest are not shown neither.

```
package com.flavien.rouiller.irchelrun;

import java.io.BufferedReader;
import java.io.File;
import java.io.FileOutputStream;
import java.io.FileReader;
import java.io.IOException;
import java.io.PrintStream;
import java.util.ArrayList;
import java.util.Scanner;

import android.annotation.SuppressLint;
import android.app.Activity;
import android.app.AlertDialog;
import android.content.Context;
import android.content.DialogInterface;
import android.content.SharedPreferences;
import android.hardware.Camera;
import android.hardware.Camera.Parameters;
import android.location.Location;
import android.location.LocationManager;
import android.media.CamcorderProfile;
import android.media.MediaRecorder;
import android.os.Bundle;
import android.os.Handler;
import android.os.PowerManager;
import android.os.Vibrator;
import android.util.Log;
import android.view.Menu;
import android.view.SurfaceHolder;
import android.view.SurfaceView;
import android.view.View;
import android.widget.Button;
import android.widget.Toast;

import com.google.android.gms.maps.CameraUpdateFactory;
import com.google.android.gms.maps.GoogleMap;
import com.google.android.gms.maps.GoogleMap.OnCameraChangeListener;
import com.google.android.gms.maps.GoogleMap.OnMyLocationChangeListener;
import com.google.android.gms.maps.MapFragment;
import com.google.android.gms.maps.model.BitmapDescriptorFactory;
import com.google.android.gms.maps.model.CameraPosition;
import com.google.android.gms.maps.model.LatLng;
import com.google.android.gms.maps.model.MarkerOptions;

/**
 * This class is the activity of the program that displays the map to the user
 * This activity also records a video through the front cam and interactions of the user with the
screen
 * The activity also records the position of the user
 * Everything is written into two output files
 *
 * @author Flavien Rouiller
 *
 */
@SuppressLint("WorldReadableFiles")
public class Map extends Activity  implements SurfaceHolder.Callback, OnCameraChangeListener,
OnMyLocationChangeListener {

        private String userNb;
        private GoogleMap map;
        private Handler mHandler = new Handler(); // To zoom a bit later to the user
```

```
                                                                                                //
position

        public String outputFileDir = "/storage/extSdCard/IrchelRun/OutputFiles";
        public String saveFileDir = "/storage/extSdCard/IrchelRun/Saves";

        PowerManager.WakeLock wl;
        PowerManager pm;

        // The camera instance and associates
        private Camera mCamera;
        private SurfaceHolder surfaceHolder;
        private SurfaceView surfaceView;
        public MediaRecorder mrec = new MediaRecorder();

        //The number of time the user touched the screen altogether
        private int nbCameraChange;
        private LatLng lastTarget = new LatLng(-9999, -9999);
        private Float lastZoom = (float) -9999;
        private Float lastBearing = -8888f;

        //Under TP or not
        private boolean tpState;

        //The time of the last position change for avoiding to big amount of data
        private long lastPosUpdate = System.currentTimeMillis();


        /**
         * Define what happens when the activity is created
         */
        @Override
        protected void onCreate(Bundle savedInstanceState) {
                super.onCreate(savedInstanceState);
                setContentView(R.layout.activity_map);
        }

        /**
         * Deal with the menu accessible through the menu button
         */
        @Override
        public boolean onCreateOptionsMenu(Menu menu) {
                return true;
        }

        /**
         * This is launched when the activity starts, after being created
         */
        @SuppressWarnings("deprecation")
        @Override
        protected void onStart() {
            super.onStart();  // Always call the superclass method first

            /*
                 * We get the current user number and is there already a file of points saved
                 */
                getUserNb();

                if (Globals.POINTS.isEmpty()){
                        upDatePtListFrmSave();
                }

                //Get the time pressure state
                tpState = getTpState();


                /*
                 * This part focus on the map and basics settings of it
                 */
                map = ((MapFragment) getFragmentManager().findFragmentById(R.id.map))
                                .getMap(); // Find the map
                map.setMyLocationEnabled(true); // Set the location finder
                map.setOnMyLocationChangeListener(this);

                //Add the markers
                addMarkers();
```

```java
		/*
		 * Prevent the screen from going to sleep
		 */
		pm = (PowerManager) getSystemService(Context.POWER_SERVICE);
		wl = pm.newWakeLock(PowerManager.SCREEN_DIM_WAKE_LOCK, "My Tag");
		wl.acquire();

		/*
		 * Create an instance of Camera and deal with surface for preview Note :
		 * not possible to record if no preview -> preview set to 1px in xml
		 */
		mCamera = null;
		mCamera = Camera.open(1);
		surfaceView = (SurfaceView) findViewById(R.id.surface_camera);
		surfaceHolder = surfaceView.getHolder();
		surfaceHolder.addCallback(this);
		surfaceHolder.setType(SurfaceHolder.SURFACE_TYPE_PUSH_BUFFERS);

		/*
		 * Center the map to the zone or to the last saved state
		 */
		SharedPreferences sharedPref = getSharedPreferences("myPrefs",
				MODE_WORLD_READABLE);

		LatLng pos = new LatLng(sharedPref.getFloat("CamLat", Globals.DEFAULTLAT),
				sharedPref.getFloat("CamLng", Globals.DEFAULTLNG));

		map.moveCamera(CameraUpdateFactory.newLatLngZoom(pos, sharedPref.getFloat("CamZoom",
Globals.DEFAULTZOOM)));

		/*
		 * Set the good map type
		 */
		boolean buttonState = sharedPref.getBoolean("buttonSat", false);
		setMapSat(buttonState);


		/*
		 * Set a delay to start recording
		 */
		mHandler.postDelayed(new Runnable() {
			public void run() {

				// Start recording
				try {
					startRecording();
				} catch (Exception e) {
					String message = e.getMessage();
					Log.i(null, "Problem Start" + message);
					mrec.release();
				}
			}
		}, Globals.STARTRECDELAY);

		//The listener to record user interaction
		nbCameraChange = getNbOfMoves();
		map.setOnCameraChangeListener(this);
	}

	/**
	 * What happens when paused (partially visible)
	 */
	protected void onPause() {
		super.onPause();

		// Release the screen
		wl.release();

		//Release the surface
		surfaceHolder.removeCallback(this);
		surfaceHolder = null;
		surfaceView = null;

		// Stop the video recording
		stopRecording();

		//Deal with the number of touches
```

```java
        setNbOfMoves(nbCameraChange + getNbOfMoves());

        //Save the current position of the camera
        saveCameraPos();

        //Write the file with the point of the user
        writeSavePtFile();
}

/**
 * Add the markers to the map
 */
@SuppressWarnings("rawtypes")
public void addMarkers() {

        //measure the number of points and make a copy of it
        int nbPoints = Globals.POINTS.size();
        ArrayList curPtArray = Globals.POINTS;

        float color;


        for (int i = 0; i < nbPoints; i++) { //For each point

                ArrayList curPt = (ArrayList) curPtArray.get(i);
                double curLon = (Double) curPt.get(0); //Get its lon & lat & color
                double curLat = (Double) curPt.get(1);
                color = (Float) curPt.get(2);

                map.addMarker(new MarkerOptions().position(  //and add it to the map
                                new LatLng(curLat, curLon)).icon(
                                BitmapDescriptorFactory.defaultMarker(color)));
        }

        map.addMarker(new MarkerOptions().position(  //and add it to the map
                        new LatLng(Globals.DEPLAT, Globals.DEPLNG)).icon(
                        BitmapDescriptorFactory.fromAsset("arrival_Icon36.gif")));

}

/**
 * Get the user number from the Sharedprefs and store it in userNb
 */
@SuppressWarnings("deprecation")
private void getUserNb() {
        SharedPreferences sharedPref = getSharedPreferences("myPrefs",
                        MODE_WORLD_READABLE);
        userNb = String.valueOf(sharedPref.getInt("userNb", 0));
}

/**
 * Method to write data in the file
 *
 * @param loc
 *            LOCATION the location to be written
 */
private void writeFile(Location loc, String comment) {

        String outputFileName = "OutPutUser" + userNb + ".txt";

        File f;
        FileOutputStream outputStream;
        PrintStream ps;
        try {
                f = new File(outputFileDir, outputFileName);


                if (!f.exists()){ //If the file is new
                        outputStream = new FileOutputStream(f, true);
                        ps = new PrintStream(outputStream);

                        ps.print("UserNb");    //Write the titles
                        ps.print(";");
                        ps.print("TimeStamp");
                        ps.print(";");
                        ps.print("Latitude");
                        ps.print(";");
```

```
                        ps.print("Longitude");
                        ps.print(";");
                        ps.print("Accuracy");
                        ps.print(";");
                        ps.print("Provider");
                        ps.print(";");
                        ps.print("TP");
                        ps.print(";");
                        ps.println("Comment");
                }

                if (loc != null) {

                        outputStream = new FileOutputStream(f, true);
                        ps = new PrintStream(outputStream);

                        ps.print(userNb);
                        ps.print(";");
                        ps.print(System.currentTimeMillis()); //Time
                        ps.print(";");
                        ps.print(loc.getLatitude());
                        ps.print(";");
                        ps.print(loc.getLongitude());
                        ps.print(";");
                        ps.print(loc.getAccuracy());
                        ps.print(";");
                        ps.print(loc.getProvider());
                        ps.print(";");
                        ps.print(tpState); //The time pressure
                        ps.print(";");
                        ps.println(comment);

                        ps.close(); // close stream

                }
        } catch (Exception e) {// Catch exception if any
                System.err.println("Error: " + e.getMessage());
        }
}

/**
 * Write in a file the number of camera moves, their type, amplitude etc
 * Note that the number of camera changes is from the registering of the user and is reset
only by the creation
 * of a new user
 * @param target LatLng the new Target
 *
 */
private void writeCamChangeFile(LatLng target, float zoom, float bearing, String comment){

        String outputFileName = "CamChange_User" + userNb + ".txt";

        File f;
        FileOutputStream outputStream;
        PrintStream ps;
        try {
                f = new File(outputFileDir, outputFileName);


                if (!f.exists()){ //If file is new
                        outputStream = new FileOutputStream(f, true);
                        ps = new PrintStream(outputStream);
                        //Write the titles
                        ps.print("UserNb");
                        ps.print(";");
                        ps.print("TimeStamp");
                        ps.print(";");
                        ps.print("TargetLatitude");
                        ps.print(";");
                        ps.print("TargetLongitude");
                        ps.print(";");
                        ps.print("ZoomLevel");
                        ps.print(";");
                        ps.print("Bearing");
                        ps.print(";");
                        ps.print("NbOfCameraChanges");
                        ps.print(";");
```

```java
                        ps.println("Comment");
                }

                outputStream = new FileOutputStream(f, true);
                ps = new PrintStream(outputStream);
                        ps.print(userNb);
                        ps.print(";");
                        ps.print(System.currentTimeMillis());
                        ps.print(";");
                        ps.print(target.latitude);
                        ps.print(";");
                        ps.print(target.longitude);
                        ps.print(";");
                        ps.print(zoom);
                        ps.print(";");
                        ps.print(bearing);
                        ps.print(";");
                        ps.print(nbCameraChange);
                        ps.print(";");
                        ps.println(comment);

                        ps.close(); // close stream

        } catch (Exception e) {// Catch exception if any
                System.err.println("Error: " + e.getMessage());
        }
}

/**
 * Write a file to save the points that are still to visit
 * and their color
 */
@SuppressWarnings("rawtypes")
private void writeSavePtFile(){
        String outputFileName = Globals.NAMEFILESAVEPT +"User"+ userNb + ".txt";

        int nbPoints = Globals.POINTS.size();

        File f;
        FileOutputStream outputStream2;
        PrintStream ps2;
        try {
                f = new File(saveFileDir, outputFileName);
                outputStream2 = new FileOutputStream(f, false);
                ps2 = new PrintStream(outputStream2);

                ArrayList curPtArray = Globals.POINTS;

                float color;
                double curLon;
                double curLat;

                for (int i = 0; i < nbPoints; i++) {

                        ArrayList curPt = (ArrayList) curPtArray.get(i);
                        curLon = (Double) curPt.get(0);
                        curLat = (Double) curPt.get(1);
                        color = (Float) curPt.get(2);

                        ps2.print(curLon);
                        ps2.print(";");
                        ps2.print(curLat);
                        ps2.print(";");
                        ps2.println(color);

                }
                        ps2.close(); // close stream

        } catch (Exception e) {// Catch exception if any
                System.err.println("Error: " + e.getMessage());
        }
}

/**
 * Starts the recording with the camera
 *
```

```java
 * @throws IOException
 */
	protected void startRecording() throws IOException {
		mrec = new MediaRecorder();
		mCamera.unlock();

		//Which cam instance to use
		mrec.setCamera(mCamera);
		//Where to put the preview (Obligatory, I use a 1px preview)
		mrec.setPreviewDisplay(surfaceHolder.getSurface());

		//Set the media sources
		mrec.setVideoSource(MediaRecorder.VideoSource.CAMERA);
		mrec.setAudioSource(MediaRecorder.AudioSource.MIC);

		//1 for the front camera, 0 for the the normal (back) cam
		//Quality is set in globals
		mrec.setProfile(CamcorderProfile.get(1, Globals.QUALITY));

		//Set the path and the name of the file
		long timeStamp = System.currentTimeMillis();
		mrec.setOutputFile(outputFileDir + "/Video/" + userNb + "_" +timeStamp + ".3gp");

		//Rotate the image, so that it is in the good direction
		mrec.setOrientationHint(270);

		//Prepare and launch
		mrec.prepare();
		mrec.start();
	}

	/**
	 * Stop the recording
	 * ?Maybe too many try catch?
	 */
	protected void stopRecording() {
		if (mrec != null) {
			try{
			mrec.reset();} // clear recorder configuration
			catch(Exception e){
				System.out.print(e);
			}

			try{
			mrec.stop();}
			catch(Exception e){
				System.out.print(e);
			}

			mrec.release(); // release the recorder object
			mrec = null;
		}

		if (mCamera != null) {
			try{
			mCamera.stopPreview();}
			catch (Exception e){}

			mCamera.release(); // release the camera for other applications
			mCamera = null;

		}
	}

	/**
	 * Three obligatory methods
	 * Something with the camera and related surfaces
	 */
	@Override
	public void surfaceChanged(SurfaceHolder holder, int format, int width,
			int height) {
	}

	@Override
	public void surfaceCreated(SurfaceHolder holder) {
		if (mCamera != null) {
			Parameters params = mCamera.getParameters();
```

```java
                    mCamera.setParameters(params);
            } else {
                    Toast.makeText(getApplicationContext(), "Camera not available!",
                                    Toast.LENGTH_LONG).show();
                    finish();
            }
    }

    @Override
    public void surfaceDestroyed(SurfaceHolder holder) {
            mCamera.stopPreview();
            mCamera.release();
    }

    /**
     * To find in which point the user currently is. The maximal distance
     * required to be close to the point is defined in the Globals class under
     * MAXDISTTOGOAL
     *
     * @param loc
     *             Location The location where the user is
     * @return int -999 : user is not within range of a point; 0- (n-1) the user is
     *          close to this point
     */
    private int isInWhichGoal(Location loc) {
            int goal = -999;
            int nbPoints = Globals.POINTSLOC.size();
            ArrayList<Location> curPtArray = Globals.POINTSLOC;

            for (int i = 0; i < nbPoints; i++) {// Check all points
                    Location curPt = curPtArray.get(i);
                    if (curPt.distanceTo(loc) < Globals.MAXDISTTOGOAL) {
                            goal = i;
                    }
            }
            return goal;
    }

    /**
     * Remove the point from the list in Globals
     * @param int pt the index of the point to be removed (0-(n-1))
     */
    private void removePtFromList(int pt){
            Globals.POINTSLOC.remove(pt);
            Globals.POINTS.remove(pt);
    }

    /**
     * Display the dialog that is shown when the user reach one of the goals
     */
    public void goalReachedDialog() {
            AlertDialog.Builder popDialog = new AlertDialog.Builder(this);

            //Different layouts if last point or not
            if (Globals.POINTSLOC.size() > 1) {
                    popDialog.setTitle("You have reached a target point !");
                    popDialog.setMessage("You still have " + Globals.POINTSLOC.size() + "points
to find.");
            }
            else if (Globals.POINTSLOC.size() > 0) {
                    popDialog.setTitle("You have reached a target point !");
                    popDialog.setMessage("You still have 1 point to find.");
            }
            else {
                    popDialog.setTitle("Finished !");
                    popDialog.setMessage("You can go back now.");
            }

            // Button OK
            popDialog.setPositiveButton(android.R.string.ok,
                            new DialogInterface.OnClickListener() {
                                    public void onClick(DialogInterface dialog, int which) {
                                            // Remove the dialog
                                            dialog.dismiss();
                                    }
                            });
            popDialog.create();
```

```java
        popDialog.show();
}

/**
 * What happens when the map is panned or/and zoomed
 */
@Override
public void onCameraChange(CameraPosition position) {
        nbCameraChange++;
        CameraPosition camPos = map.getCameraPosition();
        LatLng target = camPos.target;
        float zoom = camPos.zoom;
        float bearing = camPos.bearing;

        if ((target.equals(lastTarget))){
                target = new LatLng(0,0);
        }
        else{
                lastTarget = target;
        }

        if (zoom == lastZoom){
                zoom = -9999f;
        }
        else {
                lastZoom = zoom;
        }

        if (bearing == lastBearing){
                bearing = -8888f;
        }
        else{
                lastBearing = bearing;
        }
                writeCamChangeFile(target, zoom, bearing, Globals.EMPTYCOMMENT);

}

/**
 * Get the number of CamMove saved in the Shared prefs
 * @return int the number of cam Moves
 */
@SuppressWarnings("deprecation")
public int getNbOfMoves(){
        int nbOfMoves;
        SharedPreferences sharedPref = getSharedPreferences("myPrefs",
                        MODE_WORLD_READABLE);
        nbOfMoves = sharedPref.getInt("nbOfMoves", 0);

        return nbOfMoves;
}

/**
 * Set the number of moves into the Shared prefs under the label "nbOfMoves"
 * @param nbOfMoves The number of moves to be saved in SharedPrefs
 */
@SuppressWarnings("deprecation")
public void setNbOfMoves(int nbOfMoves){
        SharedPreferences sharedPref = getSharedPreferences("myPrefs",
                        MODE_WORLD_READABLE);
        SharedPreferences.Editor editor = sharedPref.edit();
        editor.putInt("nbOfMoves", nbOfMoves);
        editor.commit();
}

/**
 * Save the current pos of the camera in SharedPref
 */
@SuppressWarnings("deprecation")
private void saveCameraPos(){

        SharedPreferences sharedPref = getSharedPreferences("myPrefs",
                        MODE_WORLD_READABLE);
        CameraPosition camPos = map.getCameraPosition();

        SharedPreferences.Editor editor = sharedPref.edit();
        editor.putFloat("CamLat", (float) camPos.target.latitude);
```

```java
        editor.putFloat("CamLng", (float) camPos.target.longitude);
        editor.putFloat("CamZoom", camPos.zoom);
        editor.commit();
}

/**
 * Get the time pressure state from the SharedPref (true = Time Pressure)
 * @return boolean time pressure
 */
@SuppressWarnings("deprecation")
private boolean getTpState() {
        SharedPreferences sharedPref = getSharedPreferences("myPrefs",
                        MODE_WORLD_READABLE);
        boolean tpState = sharedPref.getBoolean("TP", false);
        return tpState;
}

/**
 * Read the file where the points that the user need to visit are and set the GLobal var
with them
 */
@SuppressWarnings({ "unchecked", "rawtypes" })
private void upDatePtListFrmSave(){

        Globals.POINTS.clear();
        Globals.POINTSLOC.clear();
        try{
            File f = new File(saveFileDir, Globals.NAMEFILESAVEPT +"User"+ userNb + ".txt");

            FileReader fr = new FileReader(f); // Open a fileReader to link to the file
            BufferedReader br = new BufferedReader(fr); // A BufferedReader allows us to
read each line individually
            String s = br.readLine(); // Now read a line, so that we can check if there is
any data in the file
            double curLon;
            double curLat;
            float color;

            while (s != null){ // Stop the loop if we read no data
                ArrayList thisPt = new ArrayList();
               Scanner sc = new Scanner(s);
                sc.useDelimiter(";");
                curLon = sc.nextDouble();
                thisPt.add(curLon);
                curLat = sc.nextDouble();
                thisPt.add(curLat);
                color = sc.nextFloat();
                thisPt.add(color);

                s = br.readLine(); // Read the next line

                Globals.POINTS.add(thisPt);
                ptToLoc(thisPt);
            }
        }
        catch(Exception e){ // If something goes wrong we do this
            e.printStackTrace(); // Simply print the error message
        }
}

/**
 * Transform a point into a Location, easier to read for addmarker
 * @param thisPt the point to be treated
 */
@SuppressWarnings("rawtypes")
private void ptToLoc(ArrayList thisPt){
        Location loc = new Location("");
        loc.setLongitude((Double) thisPt.get(0));
        loc.setLatitude((Double) thisPt.get(1));

        Globals.POINTSLOC.add(loc);
}

/**
 * The behaviour of the sat/map button
 * @param view
 */
```

```java
@SuppressWarnings("deprecation")
public void buttonSat(View view) {
        //Get the state of the button from sharedPrefs
        SharedPreferences sharedPref = getSharedPreferences("myPrefs",
                        MODE_WORLD_READABLE);
        boolean buttonState = sharedPref.getBoolean("buttonSat", false);
        //Get the button
        Button buttonSat = (Button) findViewById(R.id.buttonsat);

        //If map was displayed
        if (!buttonState) {
                //Change text to map
                buttonSat.setText("Map");
                //Change SharedPrefs
                SharedPreferences.Editor editor = sharedPref.edit();
                editor.putBoolean("buttonSat", true);
                editor.commit();
                //Change the map
                map.setMapType(2);
                //Write the info into a file
                writeCamChangeFile(new LatLng(0,0), -9999f, -8888f, "From map to sat");
        }
        else {//If sat was displayed, similar as above
                buttonSat.setText("Sat");
                SharedPreferences.Editor editor = sharedPref.edit();
                editor.putBoolean("buttonSat", false);
                editor.commit();
                map.setMapType(1);
                writeCamChangeFile(new LatLng(0,0), -9999f, -8888f, "From sat to map");
        }
}

/**
 * Set the map state corresponding to the button state
 * @param buttonSatState the state of the button (false = map displayed)
 */
private void setMapSat(boolean buttonSatState) {
        Button buttonSat = (Button) findViewById(R.id.buttonsat);
        if (buttonSatState) {
                buttonSat.setText("Map");
                map.setMapType(2);
        } else {
                buttonSat.setText("Sat");
                map.setMapType(1);
        }
}
@Override
public void onMyLocationChange(Location location) {

        //If the time since the last update is more than the time set in Globals
        if (System.currentTimeMillis() - lastPosUpdate > Globals.TIMEINTERVAL) {

        lastPosUpdate = System.currentTimeMillis();

        String comment = Globals.EMPTYCOMMENT;
        // A new location update is received.
        // The location is saved and written in the file if it comes from
        // the GPS
        if (location.getProvider().equals(LocationManager.GPS_PROVIDER)) {
                // The new location is compared to the goal points
                if (isInWhichGoal(location) != -999) {
                        comment = "Goal_" + (isInWhichGoal(location)+1);
                        // If a goal is reached, the point is removed from the list.
                        removePtFromList(isInWhichGoal(location));
                        // The map cleared
                        map.clear();
                        // and redrawn
                        addMarkers();
                        // Vibrate
                        Vibrator vibe = (Vibrator) getSystemService(Context.VIBRATOR_SERVICE);
                        vibe.vibrate(600);
                        // Show the popup to inform the user
                        goalReachedDialog();
                }
                writeFile(location, comment);
        }
        }}}
```

B - Consent Form

The University of Zurich - **Participant Consent Form** **Spring 2013**
Mobile maps usage for navigation **Participant No:**

Purpose of study

You are invited to participate in a study about the usage of mobile map. I hope to learn more about the differences between users that use those maps in different situations. This study is held in the frame of my Master Thesis.

Description of study and risks

If you decide to participate, you will be asked to fill a background questionnaire including demographic information. This will be followed by a pen and paper test. Then you will receive detailed instructions for the study. The test will take place in the Irchel park and its immediate surroundings. You will have to walk and search for places. During the test, you interactions with the smartphone, a video recording and your displacement will be recorded by the phone. The SmartBand will record your skin conductance and temperature. The test instructor will follow you during the test and will take some notes. After the study, you will be asked to fill a second, very brief, questionnaire.

The whole procedure should take approximately 45 minutes and there are no particular risks nor benefits to you from participating in this experiment.

Confidentiality and disclosure of information

Any information and data collected during this study that can lead to your identification will remain confidential. If you give your permission by signing this document, the results of this study could be published. **In any publication, information will be provided in such a way that you cannot be identified.**

Feedback to participants

If you would like to be kept informed about the results of this research, please leave your name and contact details to the experiment leader. A copy of publications resulting from this research will be sent to you when available.

p.1/3

Your consent

Your decision whether or not to participate will not prejudice your future relations with the University of Zurich. If you decide to participate, you are free to withdraw your consent and to discontinue participation at any time without prejudice.

If you have any questions, please feel free to ask us.

You will be given a copy of this form to keep.

You are making a decision whether or not to participate. Your signature indicates that, having read the information provided above, you have decided to participate.

……………………………………… ………………………………

Signature of Research Participant Signature of Experimenter

……………………………………… ………………………………

Please PRINT name Please PRINT name

………………………………………

Date and Place

REVOCATION OF CONSENT

If you do not want anymore the data collected during the experiment to be used, please send me this form.

I hereby wish to WITHDRAW my consent to participate in the research proposal described above.

……………………………………. ………………………………

Signature Date

…………………………………….

Please PRINT name

This section of Revocation of Consent should be forwarded to Flavien Rouiller, Bächlerstrasse 44, 8046 Zürich or by email : flavien.rouiller@uzh.ch

C - Background Questionnaire

This questionnaire was presented online, hence the formatting was totally different. Here is just the text of the questions similar. The online questionnaire also had some logic included to avoid asking irrelevant questions according to previous responses.

What is your date of birth?

- ___________

What is your gender ?

1. Male
2. Female

Are you a student ?

1. Yes
2. No

What is your field of study ?

In which semester are you ?

What is your occupation ?

How often do you use web map services on a computer? (Google maps, maps.search.ch, Bing maps, Here)

1. 1 Never
2. 2 Rarely
3. 3 Occasionally
4. 4 Frequently
5. 5 Very Frequently

Which web mapping do you usually use ?

1. Google maps
2. maps.search.ch
3. Bing maps
4. Here
5. Other

Do you own a smartphone ?

1. yes
2. no

Do you have regular access to a smartphone? (Partner, professional,...)

1. yes
2. no

Which operating system does it run ?

1. Android
2. iOS
3. Windows
4. Other

How often do you use maps on your smartphone ?

1. 1 Never
2. 2 Rarely
3. 3 Occasionally
4. 4 Frequently
5. 5 Very Frequently

How often do you do orienteering races (Orientierungslauf, course dorientation) ?

1. 1 Never/Dont know it
2. 2 Rarely
3. 3 Occasionally
4. 4 Frequently
5. 5 Very Frequently

How often do you play Geocaching ?

1. 1 Never/Dont know it
2. 2 Rarely
3. 3 Occasionally
4. 4 Frequently
5. 5 Very Frequently

Do you study/work at the Irchel campus ?

1. yes
2. no

Did you study/work before at the Irchel campus ?

1. yes
2. no

For how long ?

1. <1 year
2. 1-3 years
3. 4-6 years
4. >6 years

How well do you know Irchel park ?

1. 1 Not at all
2. 2 Poorly
3. 3 A bit
4. 4 Well
5. 5 Very well

How well do you know the neighbourhood around the Irchel Campus and park ?

1. 1 Not at all
2. 2 Poorly
3. 3 A bit
4. 4 Well
5. 5 Very well

D - Instructions for the Paper Folding Test

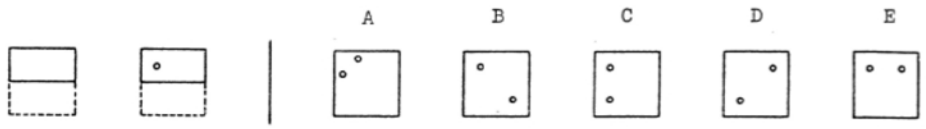
Paper Folding Test
Mobile maps usage for navigation

Spring 2013
Participant No:

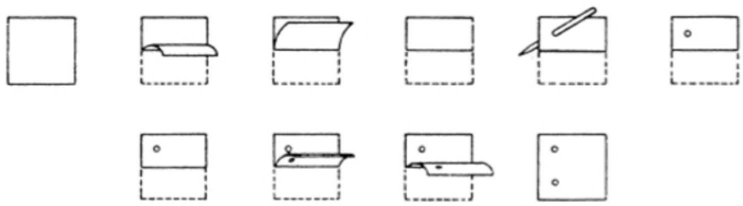
Instructions for the Paper Folding Test

In this test you are to imagine the folding and unfolding of pieces of paper. In each problem in the test there are some figures drawn at the left of a vertical line and there are others drawn at the right of the line. The figures at the left represent a square piece of paper being folded, and the last of these figures has one or two small circles drawn on it to show where the paper has been punched. Each hole is punched through all the thicknesses of paper at that point. One of the five figures at the right of the vertical line shows where the holes will be when the paper is completely unfolded. You are to decide which one of these figures is correct and draw an X through that figure.

Now try the sample problem below. (In this problem only one hole was punched in the folded paper.)



The correct answer to the sample problem above is C and so it should have been marked with an X. The figures below show how the paper was folded and why C is the correct answer.



In these problems all of the folds that are made are shown in the figures at the left of the line, and the paper is not turned or moved in any way except to make the folds shown in the figures. Remember, the answer is the figure that shows the positions of the holes when the paper is completely unfolded.

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will **not** be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have **3 minutes** for each of the two parts of this test. Each part has 1 page. When you have finished Part 1, **STOP**. Please do not go on to Part 2 until you are asked to do so.

E - Experiment instructions and scenarios

E.A - No time pressure

Instructions for the Experiment **Spring 2013**
Mobile maps usage for navigation

Goal

You have a meeting with a friend, but you are early. As you know, there is four touristic places in the neighborhood. You plan to visit them all, and then to come back to your starting point where the meeting is due. In order to avoid unnecessary detour, you plan your itinerary as rationally as possible.

The places to visit are shown as colored points on the map. The task is considered as completed as soon as you come back to the starting place after visiting all the points.

You can visit the points in any order you want.

You must walk at a speed that is your normal walking speed.

You must stay on the "official" path/road.

You can use the map in any way you want, but you must stay on the application, and avoid clicking the return or home button. You can not use any other application.

Example

The application you will be using will be the one described below. In addition to the functions described, you can use your fingers to zoom, pan, and rotate the map.

Enjoy the walk :)

E.B - Time pressure

Instructions for the Experiment **Spring 2013**
Mobile maps usage for navigation under Time Pressure

Goal

In order to apply for a new job you must have documents signed by four different people. These four people are located in four different buildings. Then you must come back to your starting point in time for the final interview with your future boss.

The location you must visit are shown on the map as colored points. The task is considered as satisfactory completed if you reach the starting place after visiting all the points in **less than 20 minutes.** This is based on the average time needed to complete the task.

You can visit the points in any order you want.

You must walk at a speed that is your normal walking speed. **Do not run !!!** The best way to gain time is to plan your itinerary as rationally as possible.

You must stay on the official way/path.

You can use the map in any way you want, but you must stay on the application, and avoid clicking the return or home button. You can not use any other application.

Quick Example

The application you will be using will be the one described below. In addition to the functions described, you can use your fingers to zoom, pan, and rotate the map.

F - Final Questionnaire

Questionnaire 2 - nTP
Mobile maps usage for navigation

Spring 2013
Participant No:

How difficult did you find this task ?

- O 1 Very difficult
- O 2 Difficult
- O 3 Neutral
- O 4 Easy
- O 5 Very easy

Did you think you had to hurry to complete the task ?

- O 1 Not at all
- O 2 A little bit
- O 3 A bit
- O 4 Pretty much
- O 5 A lot

How much stress/time pressure did you feel ?

- O 1 None
- O 2 A little bit
- O 3 A bit
- O 4 Pretty much
- O 5 A lot

Did something happen during the task that made it harder or easier ?

p.1/2

How would you enhance the map/the application for this task ?

Do you have any comment or suggestion about the experiment ?

Finally, if you want to have information about resulting publication from this experiment, please leave your email here.

G - MATLAB Script for Reducing Interaction Number of Lines

```
function shortMat = reduceCamChg( curUsr )
%Reduce the number of lines in the CamChg by removing the lines that
%are more than 500 ms apart.
%   Input the user of the number you want to treat
%   The new matrice
shortMat = [];
%Count the size of the initial file
nbLines = length(curUsr);

%for each line
for i = 1:nbLines-1
    %The difference between the current line's Timestamp and the next is
computed
    dif = curUsr(i+1,2) - curUsr(i,2);
    %If it is bigger than 500 (ms)
    if  dif > 500
        %The current line is saved in shortMat
        shortMat = vertcat(shortMat, curUsr(i,:));
    end
end

%And after the loop, a similar thing is done for the last line
dif = curUsr(nbLines,2)-curUsr(nbLines-1,2);
if dif >500
    shortMat = vertcat(shortMat, curUsr(nbLines,:));
end
end
```

H - MATLAB Script for Calculating Distance Between Two Points

```
function distance = distanceBetween2(lat1, lon1, lat2, lon2)
%distanceBetween Calculate the distance in meters bewteen two points given
%in degrees (lat1, lon1, lat2, lon2)

%Convert lat/long to radians
lat1 = lat1 * pi / 180;
lat2 = lat2 * pi / 180;
lon1 = lon1 * pi / 180;
lon2 = lon2 * pi / 180;

%calculate the earth radius at given latitude (see
%http://gis.stackexchange.com/a/20250/19039)
equatorial_Radius = 6378137;
polar_Radius = 6356752;
R = sqrt(((equatorial_Radius^2 * cos(lat1))^2 + (polar_Radius^2 * sin(lat1))^2)
/ ((equatorial_Radius * cos(lat1))^2 + (polar_Radius * sin(lat1))^2));

%Calculate lat and lon
dLat = (lat2-lat1);
dLon = (lon2-lon1);

%calculate the distance with the haversine function
a = sin(dLat/2)^2 +  sin(dLon/2)^2 * cos(lat1) * cos(lat2);
c = 2 * atan2(sqrt(a), sqrt(1-a));
distance = R * c;

end
```

I - MATLAB Scripts for preparing the visual comparison of the SCL, SCR, Speed, Time spent looking and interactions

```
function [ OP ] = SCR_SCRZoom_Glance_Spd_Intrcns( usrNb, nbSm, span )
%SCR_SCRZoom_Glance_Spd_Intrcns(usrNb, nbSm, span) [ SB, Cam, OP ] Plot the data
from
%time spent looking at the phone along with SCR and speed and interactions.
%   This function also returns a matrix that contains the GPS tracks points
%   along with information of how long the user was looking when he was
%   around that point. This can then easily be adapted for visualization in
%   ArcGis through a csv file.
%
%   The data must be loaded into the workspace. Don't forget to complete the
%   the name of OutPutUser with its number. The column number are defined
%   in the function ColNb.

%% Get the column numbers
[ColSBSCL, ColSBSecBeg, ColSBTS, ColSBSmooth, ColSBSCR, ColSBPhi, ColCamSecBeg,
ColCamTimeS, ColOPUsr, ColOPTime, ColOPLat, ColOPLon, ColOPSecBeg, ColOPSpeed,
ColNCam10Sec, ColSecCam10Sec, ColCam10SecTimeS, titleSize, legendSize,
ColGlanceTime, ColOPGlance, ColOPPerCentLooking] = ColNb( );

%See that the inputs are complete, if not set defaults
if nargin == 1
    span = 100; %span for smoothing
    nbSm = 10;  %number of smoothing iterations
elseif nargin < 3
    span = 10;
end

%% Inputs of the Data from the workspace

%Interactions
Cam = evalin('base', strcat('CamChgShUsr',num2str(usrNb)));
%Physiological data
SmartBandLog = evalin('base', strcat('SmartBandLog',num2str(usrNb)));
%GPS track
OP = evalin('base', strcat('OutPutUser',num2str(usrNb)));
%The file containing the timestamps of the beginning of the video recording
%(beginning of experiment) and the beginning of the analysis of the video.
%This is necessary to synchronize the graphs
videoTime = evalin('base', 'videoTime');

% The file containing the timestamps of when the user started and stopped
% watching at the map. (The name is very bad). The timestamps in this file
% are the timestamp of the analysis of the video. To compare with
% experiment data, they must be adapted with the videoTime file containing
% both experiment and analysis timestamps.
try
    Glance= evalin('base', strcat('TouchCountUser',num2str(usrNb)));
catch
end

%% Preparation of the data

% Remove millisec
```

```
Cam(:,2) = round(Cam(:,2)/1000);
OP(:,2) = round(OP(:,ColOPTime)/1000);
% Adjust time to central europe time from UTC
Cam(:,2) = Cam(:,2) + 2*3600;
OP(:,2) = OP(:,ColOPTime) + 2*3600;
% The time difference form the beginning (seconds from beginning)
Cam(:,ColCamSecBeg) = Cam(:,2) - Cam(1,2);
OP(:,ColOPSecBeg) = OP(:,ColOPTime) - OP(1,2);

start = min(OP(:,ColOPTime));
finish = max(OP(:,ColOPTime));
j = 1;

% It keeps only the SmartBand data that are during the experiment (i.e.
% that are within the GPS track file time range)
for i = 1:length(SmartBandLog)
    if SmartBandLog(i,11)> start && SmartBandLog(i,11) < finish
        SB(j,ColSBTS) = SmartBandLog(i,11);
        SB(j,ColSBSCL) = SmartBandLog(i,8);
        j = j+1;
    end
end
SB(:,ColSBSecBeg) = SB(:,ColSBTS) - OP(1,ColOPTime);

%% The transformation from SCL to Phi via SCR (see S.Maggi merkblatt)

%Derivative of SCL
for i = 2:length(SB)
    SB(i,ColSBSCR) = SB(i,ColSBSCL) - SB(i-1,ColSBSCL);
end

%Smoothing
SB(:,ColSBSmooth) = SB(:,ColSBSCR);
for i = 1:nbSm
    SB(:,ColSBSmooth) = smooth(SB(:,ColSBSmooth),span);
end

%Normalization
for i = 1:length(SB)
    SB(i,ColSBPhi)=(SB(i,ColSBSmooth)/(max(SB(:,ColSBSmooth))-
min(SB(:,ColSBSmooth))))*100;
end

%% Take the data from the glances count, if available
%if the glance data exists (not for all participants)
if exist('Glance', 'var')
    %Copy the existing lines into VidTime
    VidTime = zeros(26,8);
    for i=1:26
        [sizeVidTime, ~] = size(videoTime);
        for j=1:sizeVidTime
            if videoTime(j,1) == i
                VidTime(i,:) = videoTime(j,:);
            end
        end
    end

    %from millisecond to seconds and CET
    VidTime(:,2) = (VidTime(:,2)/1000) + 2*3600;
    VidTime(:,4:end) = (VidTime(:,4:end)/1000) + 2*3600;
    Glance(:,ColGlanceTime) = (Glance(:,ColGlanceTime)/1000)+2*3600;
```

```
%to compenstate for the x2 analysis speed and seconds brom beginning
Glance(:,ColGlanceTime) = Glance(:,ColGlanceTime) - VidTime(usrNb,8);
Glance(:,ColGlanceTime) = Glance(:,ColGlanceTime)*2;

%timelaps between recording and GPS first track
timeLaps = OP(1,ColOPTime) - VidTime(usrNb,2);
Glance(:,ColGlanceTime) = Glance(:,ColGlanceTime) + timeLaps;


%% Percent of time spent looking for each GPS point
%Section created for the case a map would be needed.
% for each point in OP (GPS track)
OP(:,ColOPPerCentLooking) = zeros();
for i = 1:length(OP)
    %+- five seconds
    for l = -5:5
        closest = -9999;
        distToClst = 999999999999999;
        timeToCheck = OP(i,ColOPSecBeg) + l;
        %Compare to all points in Glance and find the closest in time
        for j = 1:length(Glance)
            if abs(distToClst) > abs(timeToCheck - Glance(j,ColGlanceTime))
                distToClst = timeToCheck - Glance(j,ColGlanceTime);
                closest = j;
            end
        end

        if distToClst == 0
            %if the distance is 0, then say he was looking (limit case)
            OP(i,ColOPPerCentLooking) = OP(i,ColOPPerCentLooking) + 1;
        elseif distToClst<0 && mod(closest,2)==1
            %if distance is negative and the closest point is odd, then he
            %was looking (first line in glance correspond to the first
            %time the user stopped looking)
            OP(i,ColOPPerCentLooking) = OP(i,ColOPPerCentLooking) + 1;
        elseif distToClst>0 && mod(closest,2)==1
            %if distance positive and glance line odd, he was not looking

        elseif distToClst<0 && mod(closest,2)==0
            %...
        else
            OP(i,ColOPPerCentLooking) = OP(i,ColOPPerCentLooking) + 1;
        end
    end
end
%     transform to percent (11 because the point is also taken into account)
OP(:,ColOPPerCentLooking) = (OP(:,ColOPPerCentLooking)/11)*100;

%% Percent of time spent looking each ten seconds
% how many seconds
lastsec = max(OP(:,ColOPSecBeg));
firstsec = min(OP(:,ColOPSecBeg));
spentWatch10Sec = zeros(ceil(lastsec/10),2);
spentWatch10Sec(:,1) = firstsec:10:lastsec-1;

for i = 1:length(spentWatch10Sec)
    %+- five seconds
    for l = -5:5
        closest = -9999;
        distToClst = 999999999999999;
```

```
            timeToCheck = spentWatch10Sec(i,1) + 1;
            %Compare to all points in Glance and find the closest
            for j = 1:length(Glance)
                if abs(distToClst) > abs(timeToCheck - Glance(j,ColGlanceTime))
                    distToClst = timeToCheck - Glance(j,ColGlanceTime);
                    closest = j;
                end
            end

            if distToClst == 0
                %if the distance is 0, then say he was looking (limit case)
                spentWatch10Sec(i,2) = spentWatch10Sec(i,2) + 1;
            elseif distToClst<0 && mod(closest,2)==1
                %if distance is negative and the closest point is odd, then he
                %was looking (first line is the first time the user stopped
looking)
                spentWatch10Sec(i,2) = spentWatch10Sec(i,2) + 1;
            elseif distToClst>0 && mod(closest,2)==1
                %if distance positive and glance line odd, he was not looking

            elseif distToClst<0 && mod(closest,2)==0
                %...
            else
                spentWatch10Sec(i,2) = spentWatch10Sec(i,2) + 1;
            end
        end
    end
    %     transform to percent
    spentWatch10Sec(:,2) = (spentWatch10Sec(:,2)/11)*100;
end

%% Calculate the relevant data for the graphs
% To calculate the number of interaction (CamCh) by ten sec
CamSize = size(Cam);
CamSize = CamSize(1,1);
for i = 1:ceil(Cam(CamSize,ColCamSecBeg)/10)
    n = 0;
    for j = 1:CamSize
        if Cam(j,ColCamSecBeg) >= (i-1)*10 && Cam(j,ColCamSecBeg) < i*10
            n = n+1;
        end
    end
    Cam10Sec(i,ColNCam10Sec) = n;
    Cam10Sec(i,ColSecCam10Sec) = i*10;
end
Cam10Sec(:,ColCam10SecTimeS) = Cam(1,ColCamTimeS) + Cam10Sec(:,ColSecCam10Sec);

% Calculate the speed at each OP point
for i = 1:(length(OP)-1)
    OP(i,ColOPSpeed) = distanceBetween2(OP(i,ColOPLat), OP(i,ColOPLon),
OP(i+1,ColOPLat), OP(i+1,ColOPLon)) / (OP(i+1, ColOPTime) - OP(i, ColOPTime));
end

%last speed is zero
OP(length(OP),ColOPSpeed) = 0;

%% Drawing the graphs
close all

%x axis
xmin = 0;
```

```
xmax = OP(length(OP),ColOPSecBeg);

% First graph
subplot(5,1,1)
plot(SB(:,ColSBSecBeg),SB(:,ColSBPhi), 'LineWidth',1)
graph2d.constantline(0, 'Color',[.7 .7 .7], 'LineWidth',1);
xlim([xmin, xmax])
axis 'auto y'
title(strcat('Skin conductance response for user ', num2str(usrNb)), 'FontSize',
titleSize)
ylabel('Phi(SCR)', 'FontSize', legendSize)
box off

% Second graph
subplot(5,1,2)
plot(SB(:,ColSBSecBeg),SB(:,ColSBPhi), 'LineWidth',1)
graph2d.constantline(0, 'Color',[.7 .7 .7], 'LineWidth',1);
xlim([xmin, xmax])
ymax = mean(findpeaks(SB(:,ColSBPhi), 'MINPEAKHEIGHT', 10));
ymin = -mean(findpeaks(-SB(:,ColSBPhi), 'MINPEAKHEIGHT', 10));
if isnan(ymin)
    ymin = -10;
end
if isnan(ymax)
    ymax = 10;
end
if ymax>30
    ymax = 30;
end
ylim([ymin, ymax])
title(strcat('Zoom on skin conductance response for user ', num2str(usrNb)),
'FontSize', titleSize)
ylabel('Phi(SCR)', 'FontSize', legendSize)
box off

% Third graph
subplot(5,1,3)
bar(spentWatch10Sec(:,1),spentWatch10Sec(:,2), 1, 'k')
xlim([xmin, xmax])
axis 'auto y'
title(strcat('Percent of time spent looking over ten seconds for user ',
num2str(usrNb)), 'FontSize', titleSize)
ylabel('%', 'FontSize', legendSize)
box off

% Fourth graph
subplot(5,1,4)
plot(OP(:,ColOPSecBeg), OP(:,ColOPSpeed),'g', 'LineWidth',2)
xlim([xmin, xmax])
axis 'auto y'
ylabel('Speed [m/s]', 'FontSize', legendSize)
title(strcat('Speed of user ', num2str(usrNb)), 'FontSize', titleSize)
box off

% Fifth graph
subplot(5,1,5)
bar(Cam10Sec(:,ColSecCam10Sec),Cam10Sec(:,ColNCam10Sec),'r')
xlim([xmin, xmax])
axis 'auto y'
xlabel('Time elapsed [s]', 'FontSize', legendSize)
ylabel('Nb of interactions', 'FontSize', legendSize)
```

```
title(strcat('Interactions with the map by ten seconds for user ',
num2str(usrNb)), 'FontSize', 14)
box off

% Print it as an image to save it
set(gcf,'PaperUnits','centimeters','PaperPosition',[0 0 30 20])
print(gcf,'-dtiff','-r175',strcat('SCR_SCRZoom_Glance_Spd_Intrcns_Usr',
num2str(usrNb),'.tiff'));

end
```