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The Role of Realism and Individual Differences in Route-Learning

Investigating the Effect of Road versus Satellite Maps, Spatial Ability and Trait Anxiety in a Route-Learning Task

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Abstract

In this thesis, we investigated the effect of realism in map, spatial ability and trait anxiety. In a route-learning task involving working memory, we assessed the effectiveness of road versus satellite maps. Furthermore, the experiment was conducted in control condition and in a competition condition. Results indicated a significant effect of road map, with road maps leading to a better performance than satellite maps. Low spatial people performed worse than high spatial people, indicating that psychometric tests are good predictors for a media-based learning task. We found that high anxious participants performed worse than low anxious ones, suggesting that trait anxiety is a relevant variable to take into account when addressing individual differences. Although both spatial ability and trait anxiety are closely linked to working memory, the two variables have different impact on the task. In general, confidence about performance matched accuracy, indicating that participants were equally capable of self-assessment regarding their performance, independently of their spatial ability or trait anxiety level. Interestingly, the participants under competition condition reported higher confidence in their performance than the ones in the control group, although their accuracy or response time was not improved. Together, our findings indicate practitioners should design more abstracts maps and avoid the representation of task-irrelevant information. It also argues Geovisualization should embrace new approaches to understanding how individuals learn, in order to enhance our insight onto the construction of knowledge.

Keywords: Geovisualization, Naïve Realism, Spatial Ability, Trait Anxiety, Competition

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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.

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1 Introduction

People have used maps for hundreds of years to help them navigate the world. Usually, maps are created by cartographers, following cartographic principles (Bertin & Barbut, 1967). However, new technologies have allowed exploring new types of spatial representations, including satellite maps, animated displays, and many more. With the rise of the Internet, a wide range of different displays has reached countless users, using them every day. *Google Maps*[1] web-mapping service of reference is used by millions of people to plan routes, find locations, and explore the world. This service provides modes with different degrees of realism, ranging from the traditional 2D road map, to a photorealistic egocentric view (*Street View*). Realism is very much appreciated among users, who tend to believe that more realism is more comprehensible, as it presents more familiar representations (Hegarty et al., 2009). However, one particular type of display is not necessarily best suited for a particular type of tasks. Hence, it is important to investigate to what extent a certain display is effective, and for what kind of task. Furthermore, it is well known that individuals differ in their ability to understand spatial displays. Knowledge about what processes underpin these differences has been considered in the field of Geovisualization in order to improve spatial representations and support knowledge construction.

This thesis addresses four main research questions in relation with a route-learning task. First, it examines the effect of realism in maps. Road maps and satellite maps were chosen to address this question because they are the most likely to be used by a wide range of users. Second, it will investigate whether spatial ability, determined by psychometric tests, can predict performance. Third, it considers trait anxiety (as a predisposition to be anxious), as a potential relevant variable in understanding differences between individuals' learning methods in the area of Geovisualization. Finally, it addresses the potential effects of changes in environmental conditions. Specifically, we will investigate if a competitive environment might affect the way one performs geographical tasks.

To address the aforementioned research questions, this thesis is structured as follows. First, a literature review is conducted in Chapter 2, a necessary step in order to define the objectives

[1] Google Maps: https://maps.google.com/

and the theoretical framework underlying the elaboration of relevant hypotheses. The specific goals and hypotheses guiding this paper are described in Chapter 3. Then, the experimental design and other methodological aspects are described in Chapter 4. Finally, results will be reported in Chapter 5 and discussed in relation to the pre-established hypotheses in Chapter 6. In conclusion, the main findings will be summarized and the implications of our results will be outlined in Chapter 7.

2 Literature Review

2.1 Map Design

On a daily basis, people are confronted with their environment and have to deal with it. When people learn the layout of their environment, either spontaneously or as part of a task demand, they organize and store the information in a so-called cognitive map. This mental representation helps individuals to deal with their environment, and thus to satisfy their needs and leisure (Roche et al., 2005).

Information about a novel environment can be gathered through many different means that are commonly divided into two categories. The first, route-based knowledge, refers to any information gathered through a direct experience, that is to say through physical movement through the environment (Roche et al., 2005). To obtain this type of information, people use what (O'keefe & Nadel, 1978) call an egocentric strategy, which refers to the use of one's own body as a coordinate system that relates to the objects located within a short distance from the subject along with path integration. The second category, known as survey-based knowledge, on the other hand, refers to any information acquired from a layout representing a global and external perspective of the environment, such as map-like views or aerial photographs (Golledge et al., 1995). This information is put together as relationships between objects, independent of one's body orientation and location. Although the composition of allocentric space is often built from information acquired through route-knowledge, allowing for a representation of the configuration of the key elements in the space beyond the subject's visual field, it is also frequently acquired through media such as maps or aerial images. Both route-based and survey-based knowledge are important for the construction of an efficient cognitive map.

People are used to make use of maps to prepare and/or support their navigation in an unfamiliar environment. Usually produced by cartographers, maps were created following principles essentially promoting the simplification of the data to be displayed (Bertin & Barbut, 1967). Since one of the goals of Geovisualization is to "facilitate knowledge construction" (MacEachren & Kraak, 2001, p. 3), understanding the impact of a map's design on the acquisition of spatial information is crucial (MacEachren, 1992; Robinson & Petchenik, 1976). The evaluation of the effectiveness of maps has become particularly important with the rise of new technologies, which have lead to a vast range of different displays, from the traditional map to interactive maps in various dimensions. In conjunction with all these developments, the field of Geovisualization has begun to study cognitive processes implicated in the acquisition of map knowledge and understanding with the goal of applying this information to improve map displays (Liben et al., 2011).

Typically, people planning to perform a novel or little-known route, particularly if once in the field they will not have access to a paper or mobile map, will consult a map and try to learn the route in advance, before being immersed in the real environment. Nowadays, digital maps are provided by different web mapping services and are used by a very wide range of people. These services, such as Bing[2] or Google Maps[3], provide access to digital maps, and offer different type of views. Currently, one can look at representations of the world not only with "traditional" maps, but also with satellite images or 3D oblique views.

With technological improvement, the emergence of 3D displays has quickly increased, along with the belief that more realism is more efficient, even if basic cartographic principles tend to assert the contrary (Bertin & Barbut, 1967). It appears that peoples' preferences for certain map display do not necessarily implicate that their performance will follow their preference. This dissociation between preference and performance has been referred to as *Naïve Realism* (Smallman & Cook, 2011; Smallman & John, 2005), or *Naïve Cartography* in this specific field (Hegarty et al., 2009). It is understood as a "psychological dissonance between continued positive intuitions for realistic displays that must be maintained in the face of continued negative experience performing with them" (Smallman & Cook, 2011, p. 588). However, the research that has addressed this dissociation has reported mixed results.

In one study conducted with undergraduate students, Hegarty et al. (2009) compared the effectiveness of weather maps with and without additional realism on a forecasting task. In addition to illustrating the dissociation between preference and performance, their results suggest that additional information included in the weather map features implicates an overload of working memory (see Section 2.2 for details on this cognitive process).

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[2] Bing: http://www.bing.com/maps/

[3] Google Maps: https://maps.google.com/

Other studies have addressed potential differences between map type preference and actual efficiency. On a road selection task, in which participants had to decide on the most suitable route according to given criteria, the map type (road map or satellite images, with participants preferring the latter) did not affect performance (Wilkening, 2010). Interestingly, self-reported confidence showed that participants were more confident in their performance with satellite images than with road maps. In a further study, subjects were asked to perform a slope detection task, in which they had to find a location where a helicopter could land following previously given criteria (Wilkening & Fabrikant, 2011). The authors reported that the participants performed better with the simple slope map than with a hill-shaded relief map, thus showing that task-irrelevant information impaired performance. In this case, however, confidence was consistent with accuracy, which indicated that participants were able to assess their performance and to recalibrate their preference after performing the task.

Most studies therefore advise against enhanced map displays, especially for object location tasks, for which simple 2D displays seem more appropriate (Hegarty et al. , 2008; St John et al., 2001; Wilkening & Fabrikant, 2011). Still, different tasks may require different displays for an optimal efficiency, but this is for the moment not well known. In a task requiring shape understanding, it seems that 3D displays can be the most suitable (St John et al., 2001). However, in a study aimed at studying the effect of a 2D versus a 3D display on spatial memory tasks conducted by Cockburn (2004), there was no significant difference in performance. If indeed realism does not affect spatial memory tasks, it would signify that, when realizing these kind of tasks, people could select map type according to their preference without their efficiency being altered.

The way users extract knowledge from a map depends obviously on its display; however, further research addressing the impact of different varieties of realism in comparison with traditional maps needs to be completed to understand what display is more suited for the users and for which type of tasks.

In addition, Geovizualization also needs to address other factors that may affect the construction of knowledge. For example, maps can be used in many different contexts; still, little is known about which and how certain conditions might affect knowledge acquisition. Lately, research has addressed this question by studying the effect of time pressure on some geographic tasks (Wilkening & Fabrikant, 2011, 2013; Wilkening, 2010). In decision-making tasks, the results indicated that performance might be enhanced when testing takes place under moderate time pressure, while being impaired when a severe time limit is imposed (Wilkening & Fabrikant, 2011). Furthermore, it has been observed that individuals use different strategies to retrieve knowledge from maps (Thorndyke & Stasz, 1980). Identifying the factors that give rise to variations in the ability and strategies to read maps can give important clues to improving teaching strategies and adopting approaches to reduce inequalities in learning differences.

Understanding how people acquire knowledge from maps is a fundamental step in the improvement of map design. Differences in people's ability to navigate or to perform other geographic tasks are commonly investigated regarding individual differences in spatial ability (Hegarty & Waller, 2005), and have been so far mostly studied in relation to gender differences (Golledge et al., 1995; Montello et al., 1999; Hegarty & Waller, 2005).

2.2 Working Memory

This thesis evaluates the effect of map type, as well as the modulatory effect of individual differences, in spatial ability and trait anxiety, using a task that involves working memory. This section includes a short description of the related functions of working memory to facilitate the understanding of the following sections.

Working memory refers to a temporary storage system that can be used to encode, rehearse, and manipulate information in mind in a short time period (Baddeley, 1992). It is thus dissociated from long-term memory, which requires other cognitive functions, and is important for solving complex tasks such as some types of learning and reasoning. According to Baddeley (1992), the working memory system consists of three components. The central executive is responsible for attentional control functions. It defines performance monitoring and strategy selection. The two other components are the visuospatial sketchpad, which is devoted to the manipulation of images, and the phonological loop, whose function is to store and rehearse verbal information (Baddeley, 1992).

The central executive itself comprises three different functions (Miyake et al., 2001). The first, the inhibition function, helps to focus on task-relevant information, and prevent distraction by the irrelevant one (Eysenck et al., 2007). The second, also known as the shifting function, allows the control of how one switches from one task to another. Last but not least, the updating function induces the processing of incoming information and the replacement of old information by new one (Miyake et al., 2001).

2.3 Individual Differences

Research in individual differences has been argued to be important in the Geovisualization field (MacEachren & Kraak, 2001), as it can provide important insight into how individuals extract knowledge from maps, as well as giving relevant clues to cartographers and geographers in general to improve their displays. Most of the studies have focused on group differences, especially related to gender (Montello et al., 1999; Lawton, 2001), age (Head & Isom, 2010; Wilkniss et al., 1997) or culture (Lawton and Kallai, 2002). Most studies investigating individual differences focus on spatial ability, but other factors such as experience (Hegarty et al., 2010) or IQ (McGrew & Flanagan, 1998), have also been addressed. Despite these efforts, knowledge related to individual differences is still scarce, and their impact on performance still remains largely unknown (Wolbers & Hegarty, 2010). Some authors have suggested the relevance of exploring the role of personality factors, as they constitute important dispositions for the acquisition of mental representation (Bryant, 1982). The personality trait anxiety, despite its established link with cognitive function (e.g., Eysenck & Calvo, 1992; A. H. Robinson & Petchenik, 1976), has received little attention in the field of Geovisualization.

2.3.1 Spatial Ability

Spatial ability is defined by Hegarty and Waller as the "ability to represent and process spatial information" (Hegarty & Waller, 2005, p. 121), an ability that is useful in countless daily situations. Indeed, it is crucial for subjects of any living species to know where they are, where they come from and where they want to go. Even more important to survive is to know how to connect the dots, in other words how to navigate from one point to another. However, this ability varies among individuals, and research has attempted to define and classify spatial ability (for a review, see Hegarty & Waller, 2005). Spatial ability is commonly divided into different factors involving different cognitive processes, with spatial visualization and spatial orientation being considered as the most important. Several psychometric tests, frequently based on paper-and-pencil approaches consisting of multiple-choice questions, were developed to assess spatial ability according to these factors. For example, spatial visualization, which refers to the mental manipulation, rotation or inversion of objects, without the need to involve one's own reference (Hegarty & Waller, 2005), can be assessed through the paper folding test or the Vandenberg's Mental Rotation test. Because mental rotation implies the ability to store information while processing it at the same time, spatial ability, and especially spatial visualization, has been linked to working memory (Miyake et al., 2001).

While psychometric tests are obviously suited to predict performance in small-scale spatial tasks, research that addresses the link between individuals' results at these tests and performance in large-scale environments is still scarce. It seems that some tests could predict performance on the field when people are asked to learn a new and complex environment within a short amount of time (Hegarty & Waller, 2004). However, in general, it seems that while psychometric tests are good predictors of how a person learns from visual media, they are of little help in predicting most of learning from direct experience (Hegarty et al., 2006).

Much of the research has actually focused on differences between groups, especially gender effects. Several studies have reported that males and females differ in their spatial abilities. For example, males tend to outperform females in mental rotation tasks, while women outperform men in spatial memory tasks (Montello et al., 1999). Gender differences have also been pointed out regarding way-finding strategies. Men tend to use more cardinal directions, while women tend to use landmarks more to orientate themselves (Montello et al., 1999). On self-reported spatial ability questionnaires, females often report lower spatial ability than males (Lawton, 1994).

Research addressing spatial abilities regardless of gender differences has reported interesting results on other factors related to differences in spatial strategies. In a study addressing disposition to the alignment effect[4], Pazzaglia and Beni, (2006) suggested that people with low mental rotation ability have more difficulty to integrate spatial structures than people with high mental rotation abilities. Moreover, low spatial people tend to focus on landmarks, while

[4] The alignment effect was first studied with regard to knowledge extraction from "You-Are-Here" maps, and is called after the impaired performance in geographical tasks, such as self-orientation or pointing tasks, when the environment's reference frame is not aligned with the one of the map with the initial knowledge (Levine, 1982).

high spatial people used both salient landmarks and more complex survey perspective (Pazzaglia & Beni, 2006). Interestingly, a recent study investigated discrepancies between preferences for map type and actual performance (Smallman & Cook, 2011), and asked participants to report their preferences before and after performing terrain understanding tasks. Before the tasks, both high and low spatial participants showed a preference for more realistic displays. After the task, participants that scored well at the Vandenberg Mental Rotation Test recalibrated their preference, while low spatial participants did not. High spatial people preferred displays with less information, with which they had a better performance. However, low spatial people continued to show preference for more realistic displays, even if these displays impaired their performance, suggesting they were not able to evaluate their own performance accurately (Smallman & Cook, 2011).

2.3.2 Trait Anxiety

The general term anxiety includes two different conditions, state anxiety and trait anxiety. This difference has been established by the personality trait approach in psychology, based on the early development of the concept by Spielberger (1972). State anxiety is defined as "an aversive emotional and motivational state occurring in threatening circumstances" (Eysenck et al., 2007, p. 336), while trait anxiety refers to the predisposition of an individual to react to the world in general, and is personality-related. According to Eysenck et al. (2007), state anxiety is the result of the interaction of both trait anxiety and situational stress. The literature also refers to anxiety disorder (e.g. general anxiety disorder, phobia, or panic disorder) as different from trait or dispositional anxiety (Bar-Haim et al., 2007; Robinson et al., 2013). In fact, trait anxiety, state anxiety and anxiety disorders must be considered as separated concepts, even if they often overlap to different degrees (Bar-Haim et al., 2007). Therefore, for the purpose of this thesis, it is important to note that research on trait anxiety focuses on individual differences naturally occurring in a normal population, and it does not address a clinical one.

Studies have shown that anxiety improves the capacity to detect and process danger. Indeed, anxious people show an attentional bias toward threatening stimuli in the environment (Bar-Haim et al., 2007). This aspect can be considered as *adaptative*, since it promotes survival. However, anxiety is also responsible for numerous impairments in cognitive processes, leading for example to easy distraction and concentration difficulties, which can become a burden in individuals' daily social and working life (Kessler et al., 2009; Vytal et al., 2013).

Different theories have been developed to address the effect of anxiety on cognition. The Attentional Control Theory is a development of the earlier Processing Efficiency Theory (Eysenck & Calvo, 1992). The Processing Efficiency Theory states that worry is the "component of state anxiety responsible for effects of anxiety on performance and efficiency" (Eysenck et al., 2007, p. 337), and appears more easily in individuals with high trait anxiety. The authors suggest that worry affects performance in cognitive tasks in two ways. On one hand, it diminishes the attentional resources required for the task on hand. Accordingly, performance in cognitive tasks, especially working-memory tasks, will be therefore impaired. However, on the other hand, it was also proposed that high anxious people would anticipate the negative consequences of their poor performance, thus having the incentive to increase their effort to perform well and to avoid those negative consequences (Eysenck & Calvo, 1992). To do so, individuals would use alternative resources and strategies. As a result, high anxious people's performance would be as effective (i.e. equally accurate), but less efficient, (i.e. they would need more time and /or mental effort to reach the same result). However, when auxiliary resources are not available (for example under high time constraint), performance would be impaired in efficiency and effectiveness. Furthermore, they suggest that changes in the task or environmental conditions can affect performance in accuracy, as high anxious people would not have the same effort margin than low anxious people. When given a monetary compensation relative to performance, which should work as an incentive to increase effort, studies have reported an increase in performance in low anxious people but not in high anxious ones, suggesting that they had already increased their effort to perform the task and attain the same results than low anxious participants (Eysenck, 1985).

The subsequently developed Attentional Control Theory (ACT) adds some additional assumptions to the original theory (Eysenck et al., 2007). Processing Efficiency Theory accounted for the central executive function of working memory to be affected by anxiety. ACT specifies that the inhibition and shifting functions are the most affected. This has as effect to increase the attention to stimuli more than the goal. For high anxious individuals, these stimuli are for example worry, and will therefore distract them for task relevant stimuli. Accordingly, anxious people would fail to neglect surplus of information and would thereby be impaired in selecting the relevant one for the task on hand. Furthermore, the differentiation of the nature of stimuli and their processing is therefore also a complementary notion introduced by the ACT. The theory assumes that distraction, a key element of the theory, will be greater when stimuli are threat-related than when they are neutral (Eysenck et al., 2007).

It is well established that the attentional system of anxious individuals is biased in favour of threat-related stimuli in the environment (Bar-Haim et al., 2007), but the effect of anxiety on other cognitive processes is less known. In a review, Robinson et al. (2013) reported that the attentional bias present in high anxious people is responsible for attentional control deficits, impairing efficiency but not systematically effectiveness, as was predicted and observed by Eysenck et al. (2007). This review also reports that anxiety seems to affect working memory capacity, but not accuracy, and increased response time, which is consistent with the ACT. In addition, the review reports an effect of enhanced state anxiety on both verbal and spatial working memory, suggesting that the arousal of anxiety plays a bigger role than the apprehension of threat. The review also presents evidence indicating that long-term memory does not seem to be affected by trait anxiety. Regarding more complex functions that require a combination of cognitive processes, the review reported an effect of trait anxiety on decision making, for example on gambling games and on spatial navigation. However, planning does not seem affected by trait anxiety.

2.4 Competition

Competition is present in numerous fields, such as education, business and sports, and has a strong potential to modify our behaviour. In this thesis' experimental part, competition was introduced as a manipulation to assess the performance of participants when performing under this particular social pressure, as a way to simulate a potential stressor and/or incentive from everyday life.

The concept of competition refers to individuals or groups "fighting" for a resource, or a gain, (M. Deutsch, 2006) and is typically linked to differences in the outcome. Indeed, after such a struggle, the outcome results in winners and losers. Thus, competition is a means to increase one's benefit or to get a reward according to one's success. It is considered to have both positive and negative sides. Regarding the former, competition is regarded as an incentive to do one's best, and is also associated with fun (Stanne et al., 1999). Accordingly, competition is considered as a means to enhance performance; for example, it is largely promoted in companies to increase their profits. Regarding the latter aspect, competition is also considered as negative, destructive, and divisive, as it separates involved parties into winners and losers, ranking people according to their performance, and inducing anxiety impairing performance (M. Deutsch, 2006).

Early research showed that seeking benefit, or victory, can be attributed to social comparison (Messick & Thorngate, 1967). Hence, individuals do not only pursue a personal goal, but also seek relative benefit. When they note a discrepancy between theirs and other parties' payoffs, individuals are prompted to develop strategies to reduce this discrepancy. Commonly, individuals will adopt new, higher, personal standards and increase they effort to reach them, which in turn will enhance their performance (Messick & Thorngate, 1967). Suboptimal strategies can also be adopted. Individuals may cheat, or, for example, exceed their pre-set limit in an auction (Ku et al. , 2005).

Anxiety is prevalent in competitive situations, and the assumptions of the Processing Efficiency Theory (Eysenck & Calvo, 1992) as well as the follow-up Attention Control Theory (Eysenck et al., 2007) can be applied to the competition field (see Section 2.3.2). Research has reported mixed results concerning the effect of competition on performance, with results partially being explained by the paradoxical effects of anxiety. On one hand, it is assumed that anxiety will interfere with attention to the task on hand, which will in turn reduce performance. During a motor skill task of putting and throwing a golf ball, Cooke et al. (2011) found that when anxiety was low, individuals were more likely to improve their performance. However, individuals showing high anxiety seem to be unable to mobilize more resources, and thus, their performance would not be increased by competition (Eysenck, 1985). On the other hand, anxiety is thought to increase effort in order to avoid the negative consequences of any potential poor performance. Several studies have shown increased effort under competition, but the link with anxiety was less clear. It seems that both the anticipation of a positive and negative outcome can lead to an increased effort (Bandura & Cervone, 1983).

In order to increase effort, competition should include feedback, clear competition rules, and the discrepancy between the competitors should be moderate (Stanne et al., 1999). Under these circumstances, individuals will feel incited to improve and adjust their goals to minimize the discrepancy between them and the other competitors (Garcia et al., 2006).

The physiological effects of competition also seem to have an impact on performance. Impaired performance was found to be associated with the effect of competition on muscular activity (Cooke et al., 2011). Somatic anxiety was also found predictive on a task involving physical demands (Parfitt & Pates, 1999). The stress resulting from social comparison or the apprehension of not being able to achieve a task's demand can also affect cognitive processing (Wilson, 2008). One of the hormones typically activated under stress is cortisol. Once in the blood, cortisol can gain access to the brain where it has been shown to exert complex effects on cognitive functions (Sandi, 2013). Stress and cortisol typically affect cognitive processes in different ways depending on their level. Moderate levels have positive effects, for example on memory, while high levels impair cognitive processing (Kivlighan et al., 2005). On the basis of these theories, both positive and negative effects of stress and cortisol can be induced under competition.

3 Aim of the Study and Hypotheses

Previous studies in the field of Geovisualization have identified an important role for some factors, such as certain characteristics of maps or differences in relevant cognitive aspects in subjects, in the processing of spatial and visual information. This study aims at complementing this line of research by obtaining further evidence regarding the effect of two different map types and the contribution of differences in spatial ability.

Further more, although the field of Geovisualization has begun to address individual differences in relation to the use of maps and their defining factors, the number of studies is still quite limited. For example, although personality traits are known to influence different cognitive processes, their potential role in the field of Geovisualization has not been investigated yet. This work aims to do so, by investigating, in addition to spatial ability, the possible role of trait anxiety on differences in performance in route-learning tasks related to way-finding using different types of maps. Most of the previous studies addressing the effect of anxiety performed experiments under basal, control, conditions, probably not the ones in which anxiety could have most negative effects. For this reason, to challenge our subjects, experiments in this works will assess performance not only under basal conditions, but also under competition. The context in which maps are used can indeed vary a lot, and this could potentially affect performance in map reading in certain individuals. Notably, competition is very likely to affect individuals in life situations such as learning the details of a route through map reading and recall it in order to take actions in the future (e.g., orienteering competitors, delivery people).

Thus, this study addresses the independent and combined effect of a number of different variables, both depending on the map type, on the subject's characteristics - including spatial ability and anxiety trait- and on the task context -the competitive nature. For each of them, and for their interaction, we have formulated different hypotheses (see below).

Map Type

The current study aims to examine if road maps and satellite maps are equally effective to perform a geographical learning task, or if they lead to different outcomes on several dependent factors. We assumed that map type would not affect accuracy on the task, following previously reported results (Hegarty et al., 2009; Wilkening, 2010). More specifically, we predicted that participants would perform as well with satellite maps as with road maps (Hypothesis 1). We also assumed that participants would perform equally fast with both road and satellite maps (Cockburn, 2004) (Hypothesis 2). Moreover, we predicted that participants would show more confidence with more realistic displays than with more abstract representations (Smallman & Cook, 2011; Wilkening, 2010); thus, that confidence ratings would be higher with satellite maps than with road maps (Hypothesis 3).

Spatial Ability

Regarding spatial ability, we assumed that, consistent with previous studies, participants with low mental rotation abilities would perform worse than high spatial participants (Pazzaglia & Beni, 2006) (Hypothesis 4). We also predicted that low spatial participants would take more time realizing a task involving working memory than high spatial ones (Miyake et al., 2001) (Hypothesis 5). We further assumed that low spatial participants would be aware of their difficulties and show less confidence in their performance than high spatial participants (Hypothesis 6)

Trait Anxiety

Since in certain instances, anxiety seems to work as an incentive to increase effort (Eysenck et al., 2007), we predicted that high anxious participants would perform as well as low anxious people (Hypothesis 7). Nevertheless, we assumed that they would face more difficulties, and that the increased effort would affect their response time (Eysenck et al., 2007). Therefore, we predicted that high anxious participants would use more time to accomplish the task (Hypothesis 8). Regarding confidence, we expected that worry would affect the confidence of high anxious people and that they would report lower confidence in their performance than low anxious participants (Hypothesis 9).

Competition

The competition manipulation was introduced in order to investigate if changes in environmental conditions could affect the route-learning task in general, but also if changes in cognitive processes provoked by the competition situation could affect the task in some way. We expected that competition would serve as an incentive to increase effort, and that the participants would perform better under competition than the ones in the control condition (Hypothesis 10). We also expected the participants in the competition group to be faster than the ones in the control group (Hypothesis 11). As we expected the increase in effort to lead to a better performance, we also assumed that the confidence of the participants under competition would follow their performance. Hence, we hypothesized that participants under competition would show more confidence than the ones in the control condition (Hypothesis 12).

Interactions Between Factors

In addition to observe the effects of these different independent variables on learning, we also wanted to investigate potential interactions between them. Particularly, we wanted to see if spatial ability could interact with a certain map type. We hypothesized that satellite images would represent a bigger challenge for low spatial people than high spatial ones. We assumed the additional task-irrelevant information would represent a bigger cognitive load, hence challenging working memory processes in a greater extent for low spatial participants. Hence, we predicted that high spatial participants would perform better than low spatial participants with both types of maps, but that low spatial participants would perform even worse with satellite maps than with road maps, while map type would not affect performance in high spatial participants (Hypothesis 13).

In addition, since high anxious people are likely to be distracted by irrelevant information, we expected that trait anxiety would interact with map type. Since satellite images are representing much more information, they represent many potential distractors for high anxious people. Thus, we expected that response time would be greater for satellite maps than for road maps within high anxious participants, while low anxious ones would need the same time for both types of maps (Hypothesis 14).

Furthermore, we expected an interaction between competition and trait anxiety, since the stress induced through competition would impair their ability to develop alternative strategies to cope with their cognitive difficulties. We expected that high and low anxious participants would perform equally under normal condition, while a discrepancy between their performances would emerge under competition (Hypothesis 15).

4 Method

4.1 Participants

Male students between 18 and 25 years were recruited to take part in the experiment. The reason to focus on this age window and gender was to have a homogeneous sample in order to increase statistical power by reducing the probability that other factors such as age or gender affect the task. Literature abounds with examples of differences between men and women in spatial and navigational abilities (e.g., Hund & Minarik, 2006; Lawton, 1994), including recent evidence indicating the gonadal hormones can affect visuospatial abilities (Schöning et al., 2007). There is also some evidence indicating that women generally show lower confidence for their performance in spatial tasks (Wilkening & Fabrikant, 2011; Nardi et al., 2013). Concerning anxiety, it is established that variations in the levels of ovarian hormones that occur throughout the menstrual cycle can affect mood and anxiety in women (Nillni et al., 2011; Glover et al., 2013). Therefore, experiments aiming to investigate the impact of anxiety in women should control for difference in the menstrual cycle, which largely complicate experimental design and data interpretation. Since gender modulates many variables taken into account in the study, and one of our main focuses is on individual differences, we chose to conduct the experiment only in men.

Participants were recruited using posters posted at the University of Lausanne and at the Ecole Polytechnique Fédérale de Lausanne[5] (EPFL), as well as in libraries and bars in the City of Lausanne. We also contacted students that had previously participated in experiments performed at the EPFL and had accepted to be contacted for further experiments. The subjects were told that they were recruited to participate in an experiment concerning map learning and individual differences. They were also instructed that the experiment would involve online questionnaires and a lab session at the EPFL. Our sample resulted in 120 participants, randomly assigned to either a control (n = 60) or competition (n = 60) condition.

Once the participants had been assigned a lab session, they were invited to answer some online questionnaires for about 30 minutes, containing demographic questionnaires, a French

[5] Swiss Federal Institute of Technology in Lausanne

version of the State-Trait Anxiety Inventory (STAI) (Spielberger, 1970) and a French version of Vandenbergh's Mental Rotation test (french version: Albaret & Aubert, 1996; adapted from: Vandenberg & Kuse, 1978). The online questionnaire also contained a French version of the Personality Research Form about dominance (PRF; Jackson, 1971) and a French version of the Edinburgh Handedness Inventory (Oldfield, 1971). These two latter tests were not aimed to gather data for the current research and will therefore not be explained in more detail. Lab sessions were conducted in groups of four subjects. Thirty-four sessions were conducted between October 17th and November 6th 2013. Experimental sessions took place daily either at 1:30 p.m., 3:00 p.m. or 4:30 p.m., and lasted for one hour. Each day contained one session of one condition, and two of the other; the order was counterbalanced across different days, to finally have the same number of control and competition condition sessions that were run at the different times of the afternoon. The sessions were conducted in the afternoon to reduce variations in the physiological stress response due to circadian changes. In humans, the levels of the stress hormones glucocorticoids are higher in the morning and lower in the afternoon, and different effects of stress in cognition have been found as a function of the time of testing (Lupien et al., 2002; Maheu et al., 2005). This was taken into account for the collecting of saliva samples, aimed to indicate the level of cortisol of the participants before and after competition manipulation. Participants were asked not to eat or smoke one hour before the beginning of the lab session. After having completed both the online questionnaires and the lab session, participants were paid CHF 25. In addition, they were told that one participant in each group could win between CHF 5 and CHF 30 extra, based either on their performance (competition) or on a random selection followed by a roll of dice (control condition). This study was approved by the Brain Mind institute (BMI) Ethics Committee for Human Behavioural Research of the EPFL.

4.2 Materials

4.2.1 Online Questionnaire

The online questionnaire was created on *Qualtrics*[6]. This survey platform allows to combine several questionnaires and tests within a package and facilitates data collection and analysis.

[6] Qualtrics: http://qualtrics.com/

The questionnaires battery was sent by email through a personal link to each of the participants, and was completed by them on average three days before the lab session. After giving informed consent, they were asked to answer the following questionnaire and tests (see Appendix A):

Demographics. The demographic questionnaire consisted of five questions regarding age, mother tongue, gender, household income, and the type of region where the participant lived (urban, suburban, rural).

Vandenberg' Mental Rotation test. A French version of the Vandenberg's Mental Rotation test (Albaret & Aubert, 1996) was used to determine the spatial ability of the participants. We included the instructions and figures normally used for the pen and pencil test and integrated them in the online platform. The test is composed of twenty items, such as the one represented in Figure 1. For each stimulus, four possible answers are displayed. Two of them represent a rotation of the stimulus. Participants are asked to select the figures representing the rotation. As recommended by Vandenberg and Kuse (1978), the test was performed in two parts, each including ten items. Participants had three minutes to complete each part. Points were counted following the method used by Albaret and Aubert (1996). Thus, two points were attributed when the participants gave two correct answers. One point was attributed when only one figure was selected and the selection was a correct answer. No point was attributed when one of the two choices was incorrect, both choices were incorrect, or the participants did not give any answer.

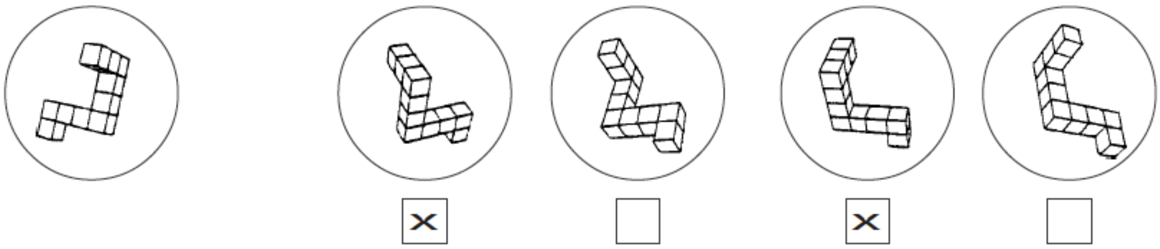

Figure 1. Vandenberg's Mental Rotation Test. On the left, a stimulus figure. On the right, four figures, of which two represent a rotation of the stimulus. The selected answers are the good answers.

State-Trait Anxiety Inventory. A French version of the Trait State-Trait Anxiety Inventory (C. Spielberger, 1970) was used to assess the level of trait anxiety of participants (STAI-T). The test consists of a 20-item questionnaire. The participant has to rate 20 statements such as 'I take disappointments so keenly that I can't put them out of my mind' on a four points scale going from 'almost never' to 'almost always'. The test aims to reflect how the participant feels generally over a long-term period, and not at a particular moment, what the state scale does. The results score from 20 to 80 points, with 20 indicating very low anxiety and 80 indicating very high anxiety.

4.2.2 Lab Session

Lab sessions took place in a lab room at the EPFL. Participants were asked to answer some paper and pencil questionnaires, and to perform a route-learning task on a computer.

Participant Booklet

A booklet was placed in front of the participants before the beginning of the experiment. It consisted of an information sheet, an informed consent form, and two copies of the state version of the State-Trait Anxiety Inventory (STAI-S). Some further demographic questions were added to complete the information collected during the online questionnaire, regarding the type and years of studies. The last page consisted of a five point Lickert scale on which participants were asked to rate their level of anxiety. This scale was completed three times throughout the experiment, and was aimed to be answered at each saliva sample collection. In addition, for the competition group, one sheet was added between the two STAI-S questionnaires, informing of the shift to competition condition, and asking the participants to estimate how they would rate themselves as compared to the other participants in the room; more precisely, they were asked in which position (first-to fourth) they expected their performance in the experimental task to be with regards to the others. An example of a participant booklet can be found in Appendix B.

State-Trait Anxiety Inventory. Participants were given a French paper version of the State STAI inventory scale (Spielberger, 1970)once before they were given the route-learning task, and once after they completed the task. The State scale contains 20 statements such as 'I feel at ease' on a four scale going from 'not at all' to 'very much so'. The test aims to assess the anxiety felt at a particular moment. The results score from 20 to 80 points, with 20 reflecting very low anxiety and 80 reflecting very high anxiety.

Working Memory Task

Route-learning task. Participants were showed animations on a computer screen representing a red dot following a route on either road or satellite maps, with the instruction to learn the trajectory of the route. At the end of the trajectory, the red dot kept frozen for two seconds. On a next slide, the question "Is it the same route as before?" appeared for one second, and was directly accompanied with a second animations, showing the same map, and a red dot following a route twice the original speed. The trajectory performed by the red dot was either the same or a different one that the one previously asked to learn. A different trajectory had always the same starting and ending point than the original one. Speed was increased to avoid a "rhythm" memory, and the map size was reduced, to avoid a photographic memory. The trajectory was shown two times in a row, after which the red dot would keep frozen for four seconds. They were told that after the two trajectories, they had four seconds to answer, and were prompted to give their response (yes or no) using the keyboard.

The task was divided into three blocks involving the same task. Block 1 and Block 2 consisted each of 12 animations based on road maps and 12 based on satellite images. The first animation displayed had a duration of 17 seconds, while the second had a duration of 13 seconds. Block 3 showed the same 24 maps than in Block 1, but at faster speed, with the duration of each trial lasting 60% of the time of the first two blocks, respectively 12 seconds for the learning animation and 8.4 seconds for the second animation.

Road Maps and Satellite Images. Twenty-four road maps and 24 satellite images from Google Maps were used during the experiment as part of the task material. They were gathered from the Google Static Maps API[7] that allows requesting a map from any browser using a http request and URL parameters, which in turn returns a map as an image. Locations were chosen with the aim to assure a certain consistency within the different maps. They were all extracted from urban regions and showed *a priori* a similar route density. However, because places are real, they reflect some different shapes. The number of maps was chosen to reduce the risk that features specific to one particular map or one particular route affects the task. An image size of 640 x 640 pixels was chosen because it is the biggest allowed by the API for free use. At

[7] Google Developers: https://developers.google.com/maps/documentation/staticmaps/?hl=fr

this size, with a zoom level of 16, maps included an area of 0.9 squared kilometres. We decided to remove labels from all the maps in order to avoid the participants to resort to verbal working memory, as we wanted to address spatial memory. Satellite maps were not presented as they are on the aerial mode of Google Maps. We chose the hybrid type, which represents roads on top of the satellite images. Here is an example of an URL used to create the maps used during this experiment:

> http://maps.googleapis.com/maps/api/staticmap?center=48.907834,%202.273298&zoom=16&size=640x640&maptype=roadmap&sensor=false&style=feature:all|element:labels|visibility:off

This URL centres the map at the given coordinates, applies the zoom level 16, and returns a 640 x 640 pixels size image. Further parameters determined the final output. The *map type* parameter can return 'roadmap', 'hybrid', or 'satellite' images. Feature parameters were used to remove labels (element:labels|visibility:off). Figure 2 (A) shows the output of the above URL. URL output images are displayed on a web page, and can be saved in any format.

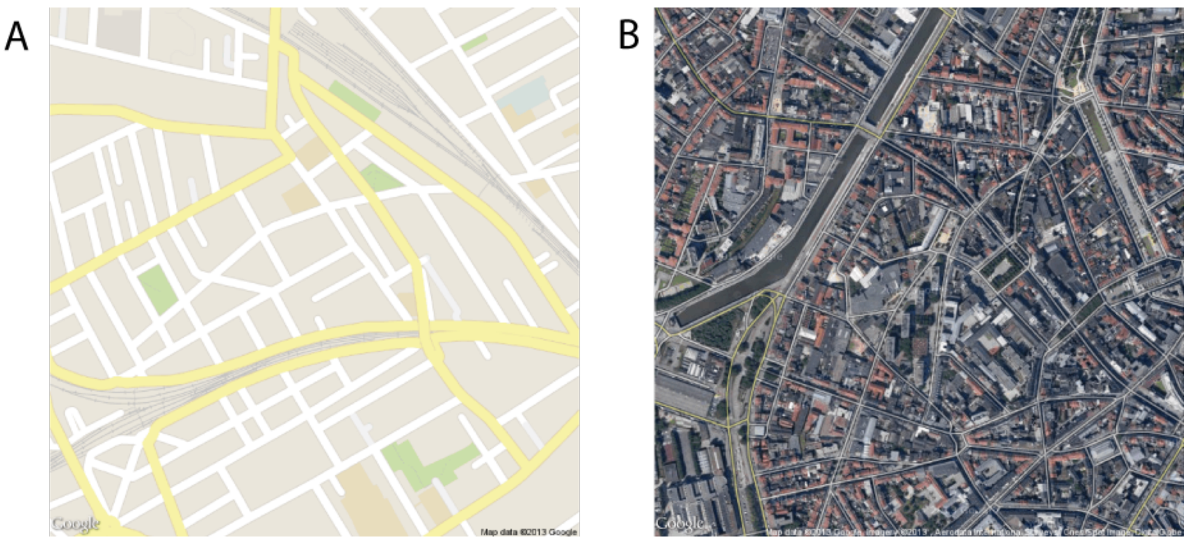

Figure 2. (A) Road Map used for the route-learning task. Map represents a part of the city of Paris. (B) Satellite Map used for the route-learning task. Map represents a part of the city of Brussels. Labels were removed from the maps to avoid text-based learning and recognition. Maps were created using Google Static Maps API (https://developers.google.com/maps/documentation/staticmaps/?hl=fr) .

Route animations. Animations were created based on the 24 roadmaps and 24 satellite images issued using the Google Static Maps API, on Adobe Flash CS4. The routes all consisted of 12 turns. They were then converted into Windows Media Video (wmv) format using Adobe After Effect CS6. They were then embedded into E-Prime®, a Psychology software that allows creating an experiment environment. We used this software to give the participants instructions related to the task and to display the animations. Moreover, E-Prime® simplifies control over the timing and facilitates data collection.

Saliva Sampling

Saliva samples were collected at three specific moments throughout the experiment. The first was taken at the beginning of the experiment, the second after the participants had completed the first block, and the third at the end of the experiment. Each time, participants were asked to have a sip of water a few minutes before. Then, they were given a Salimetrics oral swab and asked to place it under their tongue without touching it with their fingers. Once the swab was in their mouth, participants were asked to answer one of the questions in the booklet concerning their level of anxiety at the current instant. After 1.5 or 2 minutes, they were asked to return the oral swab into a storage tube, to place it in front of them and to take another sip of water (in preparation for the next sample collection). The experimenter would then place a bar-coded label on each of the tubes. At the end of the experiment, the storage tubes were frozen.

4.3 Experimental Design

4.3.1 Experimental Procedure

The study was conducted following a protocol (see Appendix C) designed to ensure homogeneity across the different experimental sessions, and that was adapted after a pilot session revealing some weaknesses of the experiment. Most of the instructions were given either on paper or on a computer screen, to reduce any possible bias due to any difference in the experimenter's behaviour. In addition, the timing of the control and competition sessions were balanced across different experimental days. In the few cases in which the number of participants per session was less than four (i.e., if some participants did not show up), the experiment was conducted under control condition.

The experimental room was 9 x 9 m and included four experimental stations including desk computers separated by boards, so that the participants could not see the other participants' screens. Before the lab session, the experimenter ran the computer and E-Prime® software, entering the session number and participants' number. The first slide of the program showed a black screen, just showing an hourglass. This way, the task could easily be run by the participants, by simply pushing a key of the keyboard, whenever they were asked to do so by the experimenter. The participant booklets were placed on the desk besides each participant's computer, according to the condition of the coming lab session (control or competition), and a pen was provided to complete the printed forms.

Each session hosted four participants who had completed the online questionnaire approximately three days before the lab session. They were first asked to take a sip of water, and to take place at one of the four experimental stations. Once they ha read the information sheet, given informed consent and completed the first STAI-S questionnaire, the first saliva sample was collected. Then, they were told that they would have to perform a route-learning task on the computer, and that all the instructions would be given on the screen.

Before the experiment started, participants were presented with a general description of the task. Then, they could practice on four trials. Following this exercise, the experimental part started with the first block of the experiment.

When the first block was finished, the second saliva sample was taken. During this procedure, the experimenter prepared the computers for the next block and the participants filled the second question about felt anxiety. In the competition condition, participants were asked to read the page concerning the competition shift, and to rate themselves regarding the other participants, even if they were not aware of their score. Participants were then informed that they could proceed to the next block, and the experimenter reminded the participants in the competition group that they were now competing against each other.

When participants were finished with the second block, the experimenter silently prepared the computers for the third part. When they were all finished with the second block, the participants were informed that they could proceed to the third one, which consisted in the same task at an increased speed.

At the end of each block, the experimenter wrote down the scores obtained by each participant. They were displayed on the screen, hidden among other information, so that the experimenter was the only one aware of the score. When the participants were finished with the third block, they were asked to complete the second STAI-S questionnaire, and fill in the demographic questions.

Each participant of the control group was then given a piece of paper, one of which included a smiling face, designating the participant that could roll a dice and win an extra amount of CHF calculated by multiplying by five the amount shown by the dice. In the competition group, the participant with the best scores during Blocks 2 and 3 was the one throwing the dice. While the last saliva sample was collected, the experimenter explained the aim of the experiment and paid the participants.

4.3.2 Independent Variables

Within variables. The experimental design is a mixed design. All the participants were exposed to 24 road maps and 24 satellite maps. They also all completed the three blocks in which the experiment was divided, each of which was composed of 24 animations. Block 1 and 2 represented exactly the same task conditions, with different maps. The third block consisted of the same task, but route animations lasted 60% of the time the animations of the two precedent blocks. This manipulation added a double constraint to the task. First, it adds workload, making the task more difficult, and put the participants under higher time pressure, which is a well-known stressor. Hence, map type and block are within variables.

Between variables. The independent variables are spatial ability and trait anxiety. Participants were divided into low and high spatial groups and into low and high anxious groups. In addition, a third independent variable was the competition condition, with participants divided into control and competition groups. State anxiety is an independent variable aiming to assess the success of the competition manipulation.

4.3.3 Dependent Variables

Accuracy. It refers to the ability of participants to identify whether the map route played on a second presentation (the trajectory running two times in a row) was the same or not as the one just played before. The variable is calculated as the rate of good answers on the total number of trials, and not just on the answered trials. If participants did not answer a question ('Is this the same route as presented before?'), the answer was considered as wrong. Hence, if a participant would only answer to five trials out of 24, and all five answers were correct, his score would be 0.21 (and not 1.0).

Response Time. The scores in this variable were calculated as the number of seconds the participants took to give each of the answers, starting from the beginning of the response animation. A limit of 17 seconds was given for Block 1 and Block 2, and of 12.4 seconds for Block 3.

Confidence. At the end of each trial, participants were asked to answer the question 'How sure are you of your answer?' to assess their confidence in the accuracy of their response on a 6 points scale, from 1 'I am not sure at all' to 6 'I am totally sure'. This index was included to assess the degree of confidence participants had about their performance in the task; that is, to differentiate between players potentially answering at random and those certain about their answers.

Accuracy pondered by confidence. This variable was calculated to assess if the participants were accurate in the assessment of their own performance. Hence, it is a way to evaluate if the participants answered correctly by chance or not, and was included as a validation of the accuracy variable. To calculate this variable, we attributed different points for their confidence ratings when their answers were correct and incorrect. The corresponding scores are displayed in Table 1.

Table 1

Points Attributed in Function of Confidence and Correctness of Response

	Points attributed	
Confidence Score	Incorrect Response	Correct Response
1	- 0.25	0.25
2	- 0.5	0.5
3	- 1	1
4	- 1	1
5	-1.5	1.5
6	- 1.75	1.75

Cortisol Level. The levels of cortisol were gathered to confirm the competition manipulation and are indicative of stress. Saliva sample were taken at three specific moments throughout the experiment. The first sample was taken at the beginning of the experiment and is not relevant regarding the manipulation. Sample 2 was taken before the manipulation and Sample 3 after the manipulation. Hence, these two measurements will indicate if the competitive manipulation was successfully implemented. Cortisol levels are given in microgram/deciliter [μg/dl]. The higher the cortisol levels, the more stressed the participants.

4.3.4 Competition Manipulation

The experimental design included two conditions, a control and a competition one, with different participants being assigned to one of them, though not explicitly informed. Participants in both control and competition conditions received the same instructions at the beginning of the experiment.

At the end of the first block, control condition implied to resume the same task as in Block 1 without any change. As for the participants in the competition group, they were asked to read and complete a form included in the participant booklet in which they were asked to subjectively rank themselves, in terms of their task performance, as compared to the other participants present in the room (thus, they had to indicate whether they expected themselves to be first, second, third, or last). On the same page of the participant sheet, a text informed them that, from that moment onwards, they will be entering a competition with the other participants of the room, so that the person with the higher score will win an additional sum, between CHF 5 and CHF 30, the actual amount depending on a roll of dice. They were told that they were competing on the basis of their accuracy and that if two or more participants would obtain similar scores, their response time would determine the winner.

4.4 Statistics

The data were analysed with the IBM SPSS software. As appropriate, repeated measures or mixed design analyses of variance (ANOVA) were performed. When the Mauchly's test of sphericity revealed a violation of the assumption of sphericity, degrees of freedom were corrected. This problem appeared only with the block variable, which is the only one with more than two levels. Each time, estimates of sphericity were higher than 0.75. Therefore, Huyn-Feldt correction was used (Field, 2000).

When interactions were found, they were confirmed with fixed factors ANOVAs, and with pairwise comparisons using Bonferroni adjustments.

When descriptive data are presented, they are given in means (M) and standard error of the mean (SEM). The results of the ANOVAs are given in F-ratios (*F*), degrees of freedoms (*df*), p-values (*p*), and the partial measure of strength of relationship (η_p^2).

Results are considered statistically significant at a p-value ± 0.05. Statistical trends are considered when p-values have a value from p = 0.1 to p = 0.05. All the figures were extracted were created with Microsoft Excel.

5 Results

Once collected, the data were analysed to answer the different research questions. We first assessed the respective effects of map type, spatial ability and trait anxiety across the three experimental blocks. The corresponding ANOVAs for each of these analyses (see specific sections below for details) included map type and block sessions as within factors, and spatial ability and trait anxiety as between factors. We then evaluated potential interactions between the different factors included in the study. In addition, for each of these comparisons we performed additional analyses to evaluate the effect of competition as an additional between-subjects factor. Given that the competition manipulation started in Block 2, the respective ANOVAs for those analyses included data only from Block 2 and 3.

After a first assessment of the obtained results, we noted that, in all performed ANOVAs, the factor "block" was always significant, probably reflecting not only the potential different cognitive processes involved in the different experimental phases but also methodological differences between the blocks (for example, trial length in block 3 was shorter than in the first two blocks). As there were no significant interactions in any of the ANOVAs between the "block" factor and any of the other factors analyzed, for the sake of clarity of the presentation of the data, we performed a second assessment of the data in which we omit this factor from the analysis and representations. It is the result of this second run of analyses (thus, not including blocks as within factor) that we present in this thesis. Finally, we evaluated potential interactions between the different factors included in the study. Given that the statistical power for this global analysis involving all the experimental factors was markedly reduced and no statistically significant interactions were revealed, we will only present the results of the ANOVAs for the analysis of the interactions of spatial ability and trait anxiety. All the results are summarize in tables in Appendix D.

5.1 Participants

One hundred and twenty participants, randomly assigned to either control (n = 60) or competition (n = 60) conditions, participated in the study. Due to technical complications, some of the participants could not complete the whole experiment, and their data were therefore excluded from the analyses. The resulting sample is composed of 104 participants between 17 and 29 years (*M* = 20.83, *SD* = 2,57), all of them (except four that had just finished their studies on the foregoing academic year) currently undergoing higher education studies (*mean years of studies* = 2.45, *SD* = 1.71).

The final control group included 54 participants (*mean age* = 21.04, *SD* = 2,61; *M* = 2.46, *SD* = 1.56) and the competition group 50 (*mean age* = 21.04, *SD* = 2.61; two of them had finished university and the mean of years of studies of the remaining 48 participants was *M* = 2.44, *SD* = 1.88).

To address potential effects of individual differences in spatial ability and/or trait anxiety, we divided the participants into: a) low and high spatial ability groups based on a median split; and b) low and high anxiety groups selected for extreme quartiles. The reason for the latter classification (instead of again utilizing a median split) is that we found that our sample's STAI-T scores (*M* = 40.47, *SD* = 7.34) were higher than reference populations, with reports typically ranging between 32-36 points for males students (Sandin, Chorot, & McNally, 2001). To be sure that the analyses were relevant to the extremes in the trait anxiety scale, we considered the participants as low or high anxious when their STAI-T scores fell, respectively, below the 25th or above the 75th percentiles.

Table 2

Participants Demographics in Function of Spatial Ability Level

Characteristic	Participants' Spatial Ability Level		
	Low spatial (*n* = 49)	High spatial (*n* = 49)	*t*-test
Age	21.47 (2.61)	20.20 (2.13)	2.631 (.010)
Years of Studies	2.89 (1.95)	2.17 (1.40)	2.09 (.039)
Scientific Major	0.73	0.92	
STAI-T	40.76 (1.18)	40.06 (0.92)	0.464 (.644)
Low anxious[a]	0.27	0.24	
High anxious[b]	0.29	0.22	

Note. Values represent means (standard deviation). T-tests represent t values (p value) from Student's *t*-tests; [a]*n = 26;* [b]n *= 26.* STAI-T: State-Trait Anxiety Inventory (SPIELBERGER, 1970).

As shown in Table 2 and Table 3, showing respectively participants' descriptives in function of participants' level of spatial ability and level of trait anxiety, anxiety levels do not differ significantly among spatial ability groups, and *vice versa*. Therefore, the two variables seem to be orthogonal, which allows us to study the effect of the two factors as unrelated individual differences.

Table 3

Participants Demographics in Function of Trait Anxiety Level

Characteristic	Participants' Trait Anxiety Level		
	Low anxious (n = 26)	High anxious (n = 26)	t-test
Age	21 (2.36)	20.57 (2.56)	0.62 (.539)
Years of studies	2.73 (2.09)	2.60 (2.0)	0.23 (.820)
Scientific Major	99.80%	0.10%	
MRT	24 (8.24)	22.38 (6.97)	0.76 (.449)
Low spatial[a]	50%	53%	
High spatial[b]	46%	42%	

Note. Values represent means (standard deviation). t-tests represent t value (p value) from Student's *t*-tests; [a]*n* = 49; [b]*n* = 49. MRT: Vanderberg Mental Rotation Test (Vandenberg & Kuse, 1978).

5.2 Assessing Manipulation Success

Two variables were measured to address the success of the competition manipulation. First, participants answered the state-anxiety questionnaire (STAI-S) twice, one at the beginning and the second at the end of the experiment. Second, saliva samples were also gathered to measure the levels of cortisol of the participants. The saliva samples able to give information on the manipulation's potential effect are the two samples taken before and after the manipulation.

A 2 (STAI-S) x 2 (competition) repeated-measure ANOVA showed that participants in both groups reported more anxiety at the end of the experiment than at the beginning of it [$F(1, 102) = 9.33$ $p = .003$, $\eta_p^2 = .084$]. However, competition did not interact with the time when the questionnaire was performed. Thus, there were no significant differences between participants in each of the two conditions in anxiety levels at the beginning or at the end of the experiment [$F(1, 102) = 0.59$ $p = .442$, $\eta_p^2 = .006$; Figure 3 (A)].

A 2 (sample time) x 2 (competition) repeated measure ANOVA was performed to assess whether the cortisol levels of the participants differ between the control and the competition group. Importantly, the analysis showed a significant interaction between the sample time and the competition group [$F(1, 102) = 4.67$ $p = .033$, $\eta_p^2 = .044$]. A paired sample *t*-test confirmed that cortisol levels are similar between the control and the competition group before the competition manipulation ($t = 5.71$, $p = <.001$), but significantly differ after the manipulation ($t = 1.65$, $p = .105$), showing that cortisol levels decreased slower for the competition group, as is illustrated in Figure 3(B).

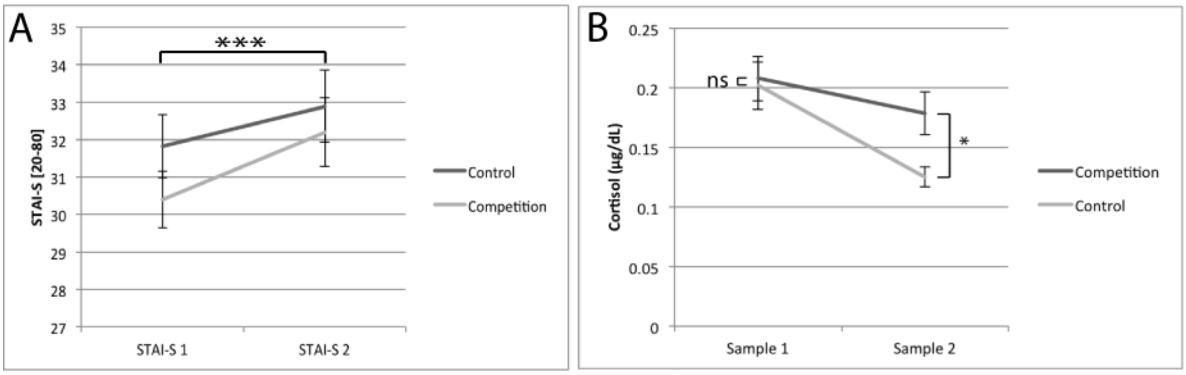

Figure 3. (A) Mean state anxiety level in control and competition groups. grouped by time of questionnaire (B) Mean cortisol level in control condition and under competition, grouped by time of sample. Error bars: ± SEM. * $p < 0.1$. *** $p < 0.005$. Cortisol levels decreased slower in participants under competition than in participants in the control condition.

5.3 The Effects of Map Type

5.3.1 The effects of Map Type

A repeated measures ANOVA was performed to analyse the effect of map type on the route-learning task across the whole study. It revealed that map type has a significant main effect on accuracy [$F(1, 103) = 7.9$, $p = .006$, $\eta_p^2 = .072$; Figure 4 (A)] and confidence [$F(1, 103) = 17.6$, $p = <.001$, $\eta_p^2 = .146$; Figure 4 (C)], but not on response time [$F(1, 103) = 2.4$, $p = .127$, $\eta_p^2 = .022$; Figure 4 (B)]. Thus, overall, participants performed better with road maps (*M* = 0.71, *SD* = 0.09) than with satellite images (*M* = 0.67, *SD* = 0.11) and showed more confidence with road maps (*M* = 4.44, *SD* = 0.78) than satellite images (*M* = 4.32, *SD* = 0.76).

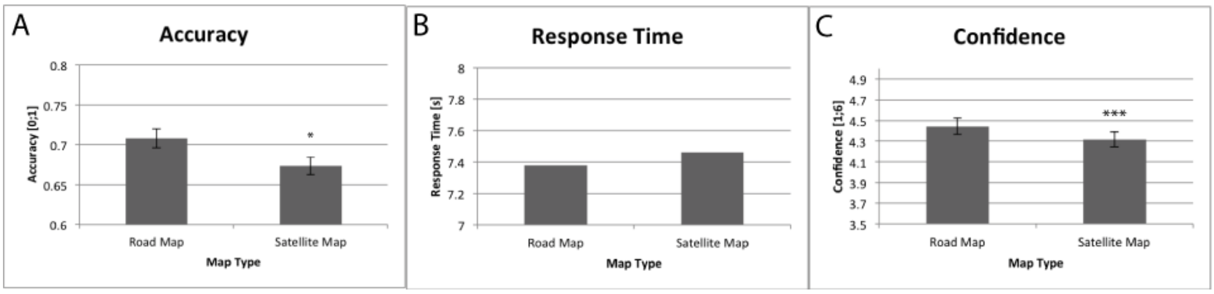

Figure 4. (A) Mean accuracy in road and in satellite images. (B) Mean response time in road and in satellite images. (C) Mean confidence ratings in road and satellite images. Error bars: ± SEM. * p < 0.1, *** p < o.oo5. Participants performed better and reported higher confidence with road maps than satellite maps.

5.3.2 The effect of Map Type under competition

A 2 (competition) x 2 (map type) mixed-design ANOVA revealed that the competition affected subjects' confidence. Under competition, participants showed more confidence than under participants in the control condition [$F(1, 102) = 4.9$, $p = .029$, $\eta_p^2 = .046$; Figure 5], but their performance and response time was not affected: accuracy: $F(1, 102) = 0.23$, $p = .614$, $\eta_p^2 = .002$; response time: $F(1, 102) = 1.96$, $p = .165$, $\eta_p^2 = .019$. This ANOVA confirmed the results obtained in the previous analysis (see Section 5.3.1), as we found a significant effect of map type on accuracy [$F(1, 102) = 7.8$, $p = .006$, $\eta_p^2 = .071$] and confidence [$F(1, 102) = 4.7$, $p = .030$, $\eta_p^2 = .046$] but not on response time [$F(1, 102) = 0.625$, $p = .431$, $\eta_p^2 = .006$]. However, there was no evidence for an interaction between competition and map type for any of the variables analysed: accuracy [$F(1, 102) = 0.08$, $p = .774$, $\eta_p^2 = .001$], response time [$F(1, 102) = 0.04$, $p = .838$, $\eta_p^2 = < .001$] and confidence, $F(1, 102) = 0.04$, $p = .843$, $\eta_p^2 = <.001$. All the results are summarized in Table 4.

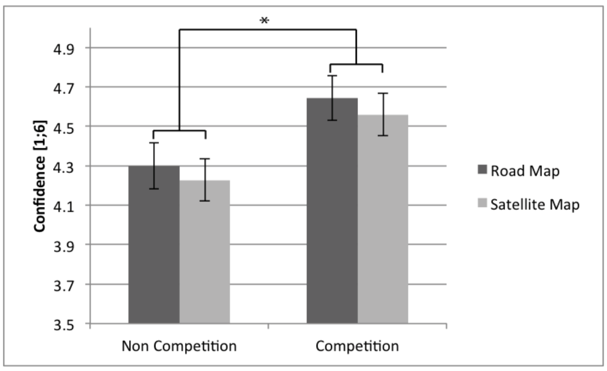

Figure 5. Mean confidence ratings in road and in satellite images, in control and under competition condition. Error bars: ± SEM. * p < 0.1. Participants showed more confidence under competition than under control condition.

Table 4

Repeated Measure ANOVA: The effect of Map Type on a Route Learning Task

	General Analysis				Competition Interaction			
Variables	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Accuracy								
Map type	7.987	1, 103	.006	.072	7.808	1, 102	.006	.071
Competition					0.225	1, 102	.614	.002
MT*C					0.083	1, 102	.774	.001
Response Time								
Map type	2.363	1, 103	.127	.022	0.625	1, 102	.431	.006
Competition					1.959	1, 102	.165	.019
MT*C					0.042	1, 102	.838	.000
Confidence								
Map type	17.6	1, 103	<.001	0.146	4.866	1, 102	.030	.046
Competition					4.903	1, 102	.029	.046
MT*C					0.039	1, 102	.843	.000

Note. * represent interactions. MT = Map Type; C = Competition; significant at p <0.05.

5.4 The Effects of Spatial Ability

5.4.1 The Effects of Spatial Ability

Accuracy

A 2 (spatial ability) x 2 (map type) mixed-design ANOVA showed that high spatial participants performed better than low spatial ones [$F(1, 96) = 8.6$, $p = .004$, $\eta_p^2 = .082$; Figure 6 (A)]. As shown in the previous section, this ANOVA confirmed that overall, participants performed better with road maps than with satellite maps [$F(1, 96) = 5.487$, $p = .021$, $\eta_p^2 = .054$]. However, no interaction between spatial ability and map type was found [$F(1, 96) = 0.14$, $p = .708$, $\eta_p^2 = .001$; Figure 6 (B)].

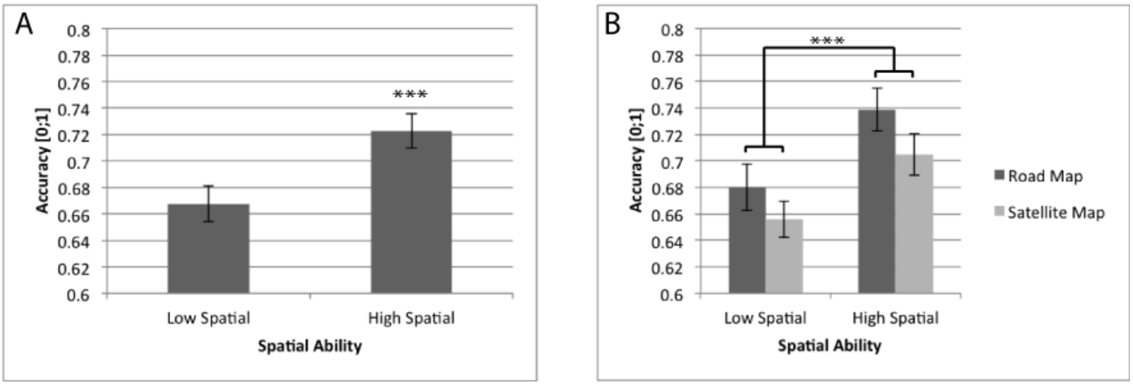

Figure 6. (A) Mean accuracy in low and in high spatial participants. (B) Mean accuracy in road and in satellite images, grouped by spatial ability. Error bars: ± SEM. *** p < o.oo5. With bot map types, high spatial participants performed better than low spatial ones.

Response Time

A 2 (spatial ability) x 2 (map type) mixed-design ANOVA indicated that spatial ability has no main effect on response time [$F(1, 96) = 1.4$, $p = .241$, $\eta_p^2 = .014$; Figure 7 (A)], and neither does map type [$F(1, 96) = 1.84$, $p = .178$, $\eta_p^2 = .019$]. However, there is a significant interaction between spatial ability and map type [$F(1, 96) = 7.9$, $p = .006$, $\eta_p^2 = .076$; Figure 7 (B)]. A repeated measure with fixed factor (spatial ability) ANOVA was performed to confirm the interaction. A pairwise comparison using Bonferroni adjustment showed that high spatial participants answered significantly faster with road maps than with satellite maps ($p = .003$) while low spatial participants took as long with both types of maps ($p = .341$).

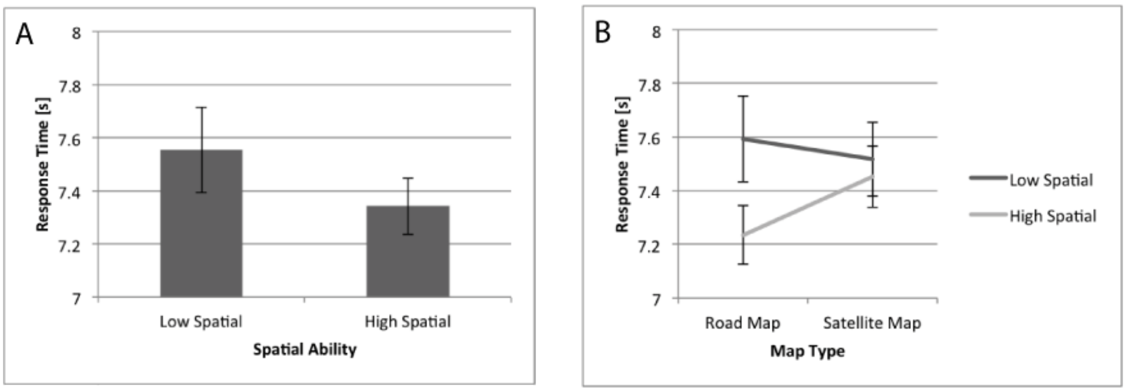

Figure 7. (A) Mean response time in low and in high spatial participants. (B) Mean response time in low and high spatial participants, grouped by map type. Error bars: ± SEM. ** p < o.o5. High spatial participants were faster than low spatial participants with road maps, but not with satellite images.

Confidence

A 2 (spatial ability) x 2 (map type) mixed-design ANOVA indicated that high spatial participants showed more confidence than low spatial ones [$F(1, 96) = 6.7$, $p = .011$, $\eta_p^2 = .065$; Figure 8 (A)]. As also noted in the partial analysis, participants showed more confidence with road maps than with satellite maps [$F(1, 96) = 14.6$, $p = < .001$, $\eta_p^2 = .132$]. However, no interaction between spatial ability and map type was found [$F(1, 96) = < .001$, $p = .945$, $\eta_p^2 = .000$; Figure 8 (B)].

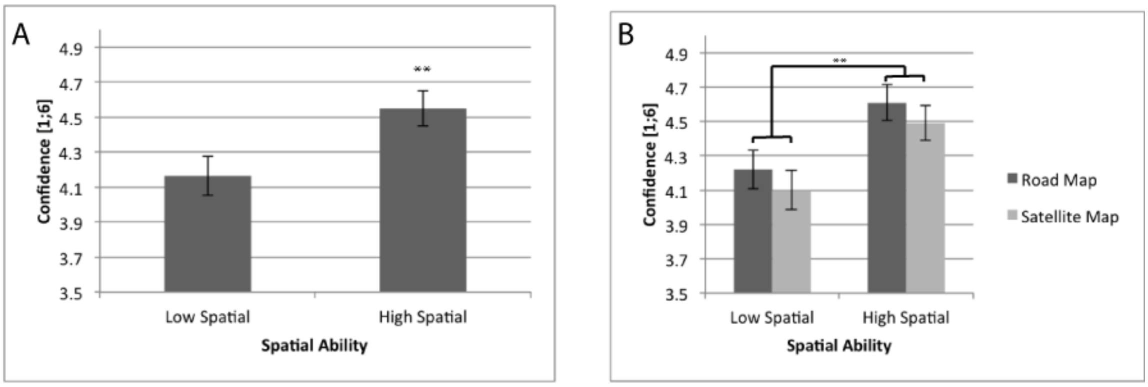

Figure 8. (A) Mean confidence ratings in low and in high spatial participants. (B) Mean confidence ratings in road and in satellite images, grouped by spatial ability. Error bars: ± SEM. ** p < o.o5. With both types of maps, high spatial participants showed more confidence than low spatial ones.

5.4.2 The Effects of Spatial Ability under Competition

Accuracy

A 2 (competition) x 2 (spatial ability) x 2 (map type) mixed-design ANOVA included the competition factor. Competition did not affect performance [$F(1, 94) = 0.00$, $p = .963$, $\eta_p^2 = .000$]. As reported above, high spatial participants performed better than low spatial participants [$F(1, 94) = 8.37$, $p = .005$, $\eta_p^2 = .082$]. Participants' performance was better with road maps than with satellite maps [$F(1, 94) = 5.9$, $p = .017$, $\eta_p^2 = .059$]. There were also no significant interactions between the different factors analysed; that is, between spatial ability and map type [$F(1, 94) = 0.00$, $p = .925$, $\eta_p^2 = .000$], map type and competition [$F(1, 94) = 0.21$, $p = .644$, $\eta_p^2 = .002$] spatial ability and competition [$F(1, 94) = 0.93$, $p = .338$, $\eta_p^2 = .010$], or between the three analysed factors [$F(1, 94) = 1.9$, $p = .169$, $\eta_p^2 = .020$].

Response Time

A 2 (competition) x 2 (spatial ability) x 2 (map type) mixed-design ANOVA showed that high spatial participants responded significantly faster than low spatial participants [$F(1, 94) = 3.9$, $p = .049$, $\eta_p^2 = .041$], while map type [$F(1, 94) = 0.74$, $p = .391$, $\eta_p^2 = .008$] and competition [$F(1, 94) = 0.77$, $p = .383$, $\eta_p^2 = .008$] did not affect the response time.

The interaction between spatial ability and map type showed a trend towards significance [$F(1, 94) = 3.71$, $p = .057$, $\eta_p^2 = .038$], confirming the findings obtained when the competition variable was not included in the study (see above, 5.4.1). However, competition did not interact with spatial ability [$F(1, 94) = 0.46$, $p = .501$, $\eta_p^2 = .005$] or with map type [$F(1, 94) = 0.17$, $p = .678$, $\eta_p^2 = .002$]. No interaction was found for the analysis of the three factors together [$F(1, 94) = 1.15$, $p = .286$, $\eta_p^2 = .012$].

Confidence

A 2 (competition) x 2 (spatial ability) x 2 (map type) mixed-design ANOVA indicated a marginal effect for competition [$F(1, 94) = 3.2$, $p = .077$, $\eta_p^2 = .033$], confirming previous analyses indicating a facilitating effect of competition in confidence. It also confirmed that high spatial people show more confidence than low spatial people [$F(1, 94) = 5.8$, $p = .018$, $\eta_p^2 = .058$] and the effect of map type, although only as a trend towards significance in this analysis [$F(1, 94) = 3.7$, $p = .057$, $\eta_p^2 = .038$]. Competition did not interact with spatial ability [$F(1, 94) = 0.46$, $p = .501$, $\eta_p^2 = .005$] or with map type [$F(1, 94) = 0.17$, $p = .678$, $\eta_p^2 = .002$] and the three factors did not interact together [$F(1, 94) = 0.43$, $p = .515$, $\eta_p^2 = .005$].

5.5 The Effects of Trait Anxiety

5.5.1 The Effects of Trait Anxiety

Accuracy

A 2 (trait anxiety) x 2 (map type) mixed-design ANOVA showed that high anxious participants performed worse than low anxious ones [$F(1, 50) = 5.7$, $p = .020$, $\eta_p^2 = .103$; Figure 9 (A)]. This analysis confirmed with a strong trend towards significance that participants tend to be more accurate with road maps than with satellite maps [$F(1, 50) = 3.8$, $p = .056$, $\eta_p^2 = .071$]. However, no interaction was found between anxiety and map type on accuracy [$F(1, 50) = 1.7$, $p = .192$, $\eta_p^2 = .0346$; Figure 9 (B).

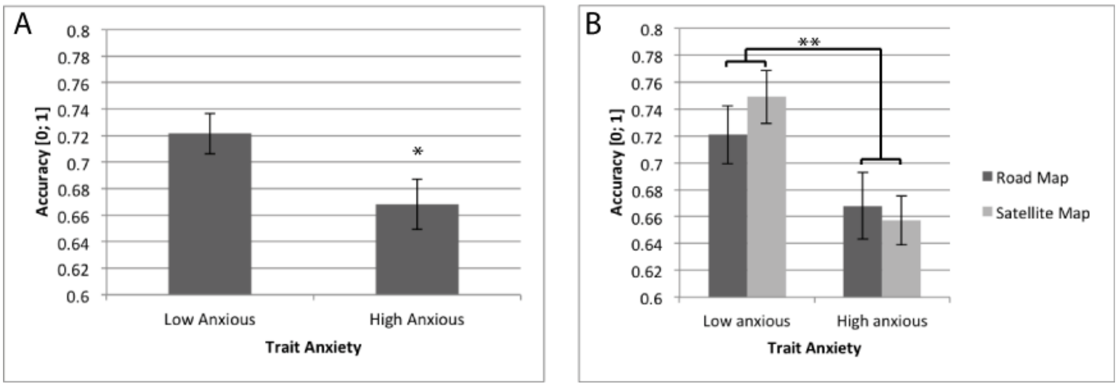

Figure 9. (A) Mean accuracy in low and in high anxious participants. (B) Mean accuracy in road and in satellite images, grouped by trait anxiety. Error bars: ± SEM. * p < o.1, ** p < o.o5. High anxious participants performed worse than low anxious ones.

Response Time

A 2 (trait anxiety) x 2 (map type) mixed-design ANOVA showed that neither trait anxiety [$F(1, 50) = 0.49$, $p = .484$, $\eta_p^2 = .010$; Figure 10 (A)] nor map type [$F(1, 50) = 1.9$, $p = .167$, $\eta_p^2 = .038$] affect response time. Likewise, the interaction between the two variables was not significant either, $F(1, 50) = 0.16$, $p = .689$, $\eta_p^2 = .003$; Figure 10 (B).

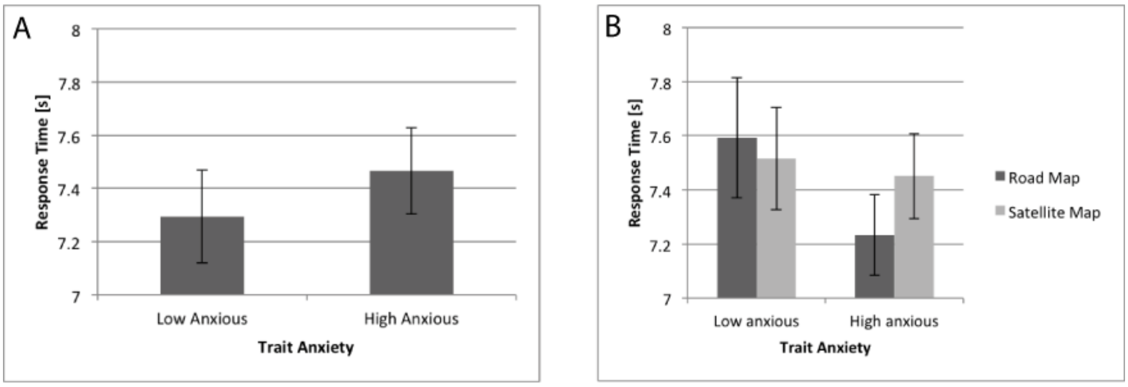

Figure 10. (A) Mean response time in low and in high anxious participants. (B) Mean response time in road and in satellite images, grouped by trait anxiety. Error bars: ± SEM.

Confidence

A 2 (trait anxiety) x 2 (map type) mixed-design ANOVA revealed that high anxious participants showed significantly less confidence than low anxious ones [$F(1, 50) = 4.0$, $p = .050$, $\eta_p^2 = .075$; Figure 11 (A)], and confirmed previous analyses indicating that participants were more confident with road maps than with satellite maps [$F(1, 50) = 8.83$, $p = .005$, $\eta_p^2 = .150$]. In addition, these analyses showed that map type and trait anxiety tend to interact [$F(1, 50) = 2.9$, $p = .095$, $\eta_p^2 = .005$; Figure 11 (B)].

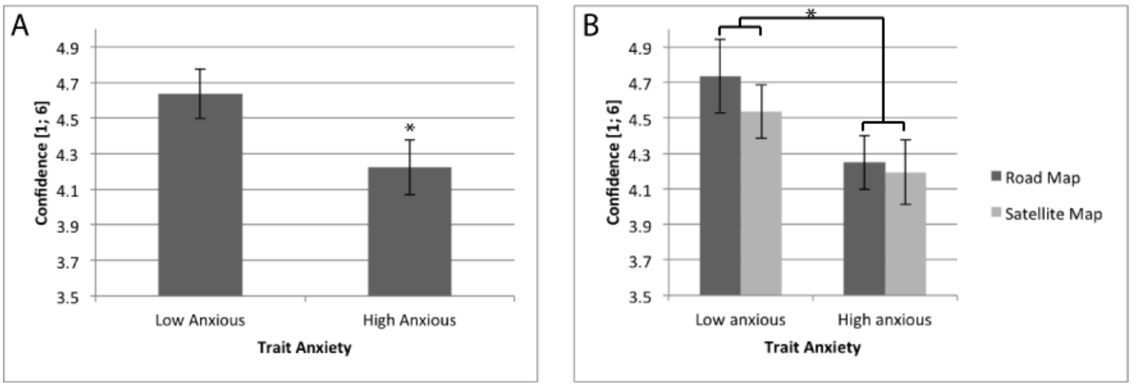

Figure 11. (A) Mean confidence ratings in low and in high anxious participants. (B) Mean confidence ratings in road and in satellite images, grouped by trait anxiety. Error bars: ± SEM. * p < o.1. High anxious participants reported lower confidence in their performance than did low anxious participants.

5.5.2 The Effects of Trait Anxiety under Competition

Accuracy

A 2 (competition) x 2 (trait anxiety) x 2 (map type) mixed-design ANOVA indicated that participants tend to perform better under competition than under normal condition [$F(1, 48) = 3.1$, $p = .083$, $\eta_p^2 = .061$] and confirmed that high anxious participants perform worse than low anxious ones [$F(1, 48) = 5.1$, $p = .029$, $\eta_p^2 = .096$]. In this analysis, the effects of map type, however, did not reach significance [$F(1, 48) = 2.1$, $p = .150$, $\eta_p^2 = .061$]. Moreover, no interaction between any of the factors analysed was found; map type and trait anxiety: $F(1, 48) = 0.57$, $p = .453$, $\eta_p^2 = .012$; map type and competition: $F(1, 48) = 0.94$, $p = .335$, $\eta_p^2 = .019$; trait anxiety and competition: $F(1, 48) = 0.05$, $p = .818$, $\eta_p^2 = .002$; Map type, trait anxiety and competition: $F(1, 48) = 0.07$, $p = .788$, $\eta_p^2 = .002$.

Response Time

A 2 (competition) x 2 (trait anxiety) x 2 (map type) mixed-design ANOVA indicated that none of the factors independently has a significant effect in response time: competition: $F(1, 48) = 0.051$, $p = .822$, $\eta_p^2 = .001$; trait anxiety: $F(1, 48) = 0.46$, $p = .498$, $\eta_p^2 = .010$; map type: $F(1, 48) = 1.8$, $p = .176$, $\eta_p^2 = .038$. However, there was an interesting interaction between the three factors [$F(1, 48) = 4.4$, $p = .041$, $\eta_p^2 = .084$]. A fixed factor (trait anxiety, competition) factorial analysis was performed to confirm this interaction. As can been seen in Figure 12, high anxious participants' response time did not differ from the low anxious ones under normal condition (n.s.). However, under competition, low anxious participants took significantly less time to answer with road maps than did high anxious participants. No interaction was found between trait anxiety and map type [$F(1, 48) = 0.48$, $p = .490$, $\eta_p^2 = .010$], between map type and competition [$F(1, 48) = 1.2$, $p = .287$, $\eta_p^2 = .024$], or between trait anxiety and competition, $F(1, 48) = 0.73$, $p = .397$, $\eta_p^2 = .015$.

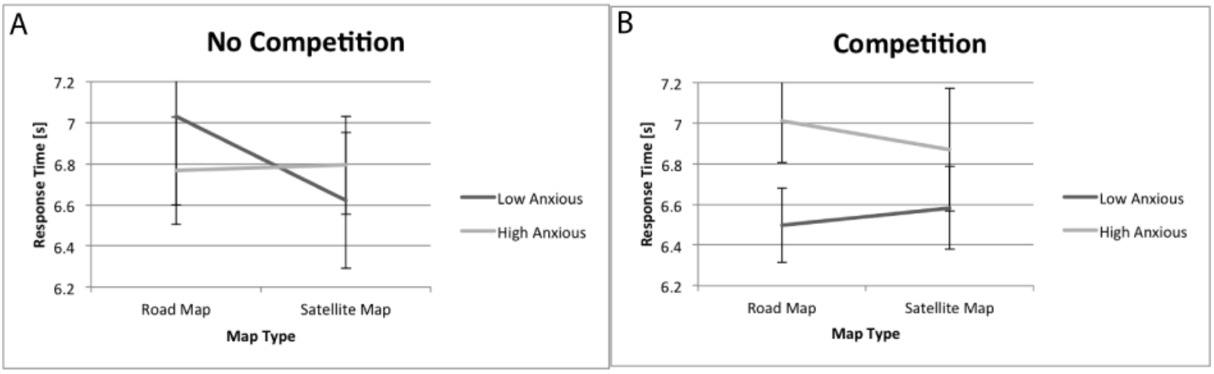

Figure 12. (A) Mean response time in low and in high anxious participants, grouped by map type, under control condition (B) Mean response time in low and in high anxious participants, grouped by map type, under competition condition. Error bars: ± SEM. * p < o.1. Under competition, low anxious participants were faster than high anxious ones to perform the task when the stimuli were road maps, but not with satellite maps.

Confidence

A 2 (competition) x 2 (trait anxiety) x 2 (map type) mixed-design ANOVA showed a significant effect of competition on confidence [$F(1, 48) = 4.9$, $p = .031$, $\eta_p^2 = .093$]. Participants in the competition group showed more confidence than the ones in the control group. However, trait anxiety and map type did not affect the confidence; trait anxiety: $F(1, 48) = 2.1$, $p = .153$, $\eta_p^2 = .042$; map type: $F(1, 48) = 2.7$, $p = .102$, $\eta_p^2 = .055$. No interaction between any of these factors was found: trait anxiety and map type: $F(1, 48) = 1.9$, $p = .166$, $\eta_p^2 = .040$; map type and competition: $F(1, 48) = 0.05$, $p = .833$, $\eta_p^2 = .001$; trait anxiety and competition: $F(1, 48) = 0.0$, $p = .991$, $\eta_p^2 = .000$; trait anxiety, map type and competition: $F(1, 48) = 0.05$, $p = .833$, $\eta_p^2 = .001$.

5.6 Interaction between Spatial Ability and Anxiety Trait

Factorial ANOVAs were performed to address the interaction between spatial ability and anxiety. In order to loose a minimum statistical power, analysis were performed with one type of map at a time.

Road Maps

Accuracy

A factorial analysis showed that high spatial participants were more accurate than low spatial ones [$F(1, 46) = 8.13$, $p = .006$, $\eta_p^2 = .150$] and that high anxious participants performed worse than low anxious ones[$F(1, 46) = 7.28$, $p = .010$, $\eta_p^2 = .137$]. However, no interaction between the two factors was found [$F(1, 46) = 1.25$, $p = .270$, $\eta_p^2 = .026$; Figure 13 (A)].

Response Time

A factorial ANOVA showed that high and low spatial participants did not differ in their response time with road maps [$F(1, 46) = 0.605$, $p = .441$, $\eta_p^2 = ..013$], and that trait anxiety did not affect response time [$F(1, 46) = 0.432$, $p = .514$, $\eta_p^2 = .009$]. The two factors did not interact [$F(1, 46) = 0.056$, $p = .814$, $\eta_p^2 = .026$; Figure 13 (B)].

Confidence

A factorial ANOVA showed that high anxious participants showed less confidence than low anxious ones [$F(1, 46) = 5.083$, $p = .029$, $\eta_p^2 = .100$], but spatial ability did not have any effect on confidence with road maps [$F(1, 46) = 0.854$, $p = .360$, $\eta_p^2 = .018$]. Furthermore, no interaction between the factors was found [$F(1, 46) = 0.014$, $p = .906$, $\eta_p^2 = .000$; Figure 13 (C)].

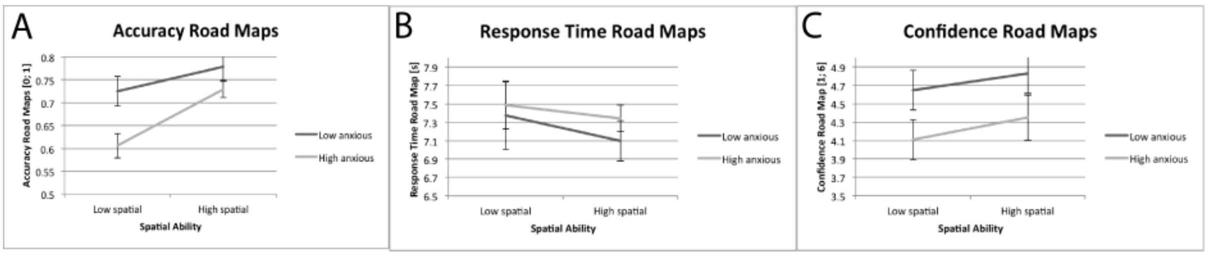

Figure 13. (A) Mean accuracy with road maps in low and high anxious participants, grouped by spatial ability. (B) Mean response time with road maps in low and high anxious participants, grouped by spatial ability. (C) Mean confidence with road maps in low and high anxious participants, grouped by spatial ability. Error bars: ± SEM.

Satellite Maps

Accuracy

A factorial analysis showed that high spatial people performed better than low spatial people with satellite maps [$F(1, 46) = 11.2$, $p = .002$, $\eta_p^2 = .196$]. Trait anxiety did not have a main effect on accuracy [$F(1, 46) = 0.657$, $p = .110$, $\eta_p^2 = .055$] and no interaction between the two factors was found [$F(1, 46) = 0.001$, $p = .982$, $\eta_p^2 = .000$; Figure 14 (A)].

Response Time

A factorial ANOVA showed that spatial ability [$F(1, 46) = 0.008$, $p = .928$, $\eta_p^2 = .000$] and trait anxiety [$F(1, 46) = 0.236$, $p = .629$, $\eta_p^2 = .005$] did not affect response time with road maps, and that the factors did not interact neither [$F(1, 46) = 0.163$, $p = .689$, $\eta_p^2 = .004$; Figure 14 (B)].

Confidence

A factorial ANOVA showed that spatial ability [$F(1, 46) = 0.440$, $p = .511$, $\eta_p^2 = .009$] and trait anxiety [$F(1, 46) = 2.584$, $p = .115$, $\eta_p^2 = .053$] did not affect response time with road maps, and that the factors did not interact neither [$F(1, 46) = 0.028$, $p = .867$, $\eta_p^2 = .001$; Figure 14 (C)].

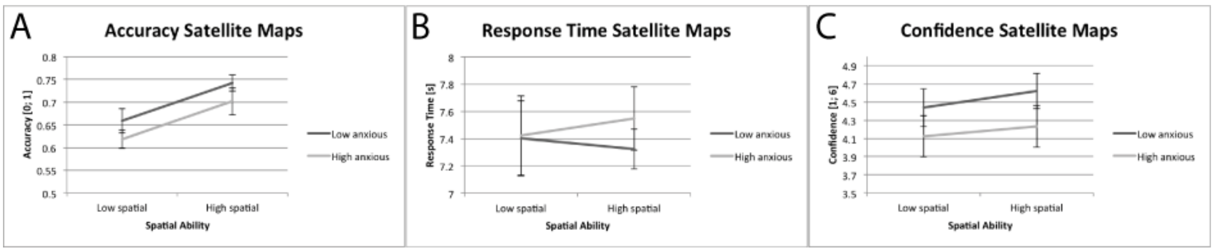

Figure 14. (A) Mean accuracy with satellite maps in low and high anxious participants, grouped by spatial ability. (B) Mean response time with satellite maps in low and high anxious participants, grouped by spatial ability. (C) Mean confidence with satellite maps in low and high anxious participants, grouped by spatial ability. Error bars: ± SEM.

5.6.1 Interaction between Spatial Ability and Trait anxiety under Competition

Road Maps

Accuracy

A factorial ANOVA showed that competition had no effect on accuracy with road maps [$F(1, 42) = 2.355$, $p = .132$, $\eta_p^2 = .053$], and spatial ability neither [$F(1, 42) = 1.195$, p = ..281, $\eta_p^2 = .028$]. However, low anxious participants tended to be more accurate than high anxious ones [$F(1, 42) = 3.081$, $p = .087$, $\eta_p^2 = .068$]. No interaction between any of these factors was found: trait anxiety and spatial ability: [$F(1, 42) = 1.98$, $p = .167$, $\eta_p^2 = .045$]; spatial ability and competition: [$F(1, 42) = 0.235$, $p = .631$, $\eta_p^2 = .006$]: trait anxiety and competition: [$F(1, 42) = 0.246$, $p = .623$, $\eta_p^2 = .006$]; spatial ability, trait anxiety and competition: [$F(1, 42) = 0.090$, $p = .766$, $\eta_p^2 = .002$]

Response Time

A factorial ANOVA showed that none of the three factors had an effect on response tme in road maps; competition: [$F(1, 42) = 0.001$, $p = .975$, $\eta_p^2 = .000$]; spatial ability: [$F(1, 42) = 0.258$, $p = .614$, $\eta_p^2 = .006$]; trait anxiety: [$F(1, 42) = 0.040$, $p = .842$, $\eta_p^2 = .001$]. There was also no interaction found between the three variables: spatial ability and trait anxiety: [$F(1, 42) = 0.015$, $p = .903$, $\eta_p^2 = .000$]; spatial ability and competition: [$F(1, 42) = 0.306$, $p = .583$, $\eta_p^2 = .007$]; trait anxiety and competition: [$F(1, 42) = 0.627$, $p = .433$, $\eta_p^2 = .015$]; spatial ability, trait anxiety and competition: [$F(1, 42) = 0.272$, $p = .605$, $\eta_p^2 = .006$].

Confidence

A factorial ANOVA showed that competition affected confidence, with participants in the competition group showing higher confidence than the one in the control group [$F(1, 42) = 5.144$, $p = .029$, $\eta_p^2 = .109$]. However, spatial ability and trait anxiety did not affect confidence in road maps; spatial ability: [$F(1, 42) = 0.430$, $p = .516$, $\eta_p^2 = .010$]; trait anxiety: [$F(1, 42) = 0.216$, $p = .645$, $\eta_p^2 = .005$]. There was also no interaction found between the three variables: spatial ability and trait anxiety: [$F(1, 42) = 0.742$, $p = .394$, $\eta_p^2 = .017$]; spatial ability and competition: [$F(1, 42) = 0.090$, $p = .766$, $\eta_p^2 = .002$]; trait anxiety and competition: [$F(1, 42) =$

0.425, p = .518, η_p^2 = .010]; spatial ability, trait anxiety and competition: [F(1, 42) = 3.685, p = .062, η_p^2 = .081].

Satellite Maps

Accuracy

A factorial ANOVA showed that spatial ability had a significant effect on accuracy with satellite images [F(1, 42) = 6.483, p = .015, η_p^2 = .134], but showed no effect of competition or trait anxiety: competition: [F(1, 42) = 0.284, p = .597, η_p^2 = .007]; trait anxiety: [F(1, 42) = 2.669, p = .110, η_p^2 = .060]. Furthermore, no interaction between any of the factors was found: spatial ability and trait anxiety: [F(1, 42) = 0.605, p = .441, η_p^2 = .014]; spatial ability and competition: [F(1, 42) = 0.381, p = .540, η_p^2 = .009]; trait anxiety and competition: [F(1, 42) = 0.668, p = .418, η_p^2 = .016]; spatial ability, trait anxiety, and competition: [F(1, 42) = 0.087, p = .769, η_p^2 = .002].

Response Time

A factorial ANOVA showed that none of the three factors had an effect on response time in satellite maps; competition: [F(1, 42) = 0.048, p = .828, η_p^2 = .001]; spatial ability: [F(1, 42) = 0.229, p = .588, η_p^2 = .007]; trait anxiety: [F(1, 42) = 0.319, p = .575, η_p^2 = .008]. There was also no interaction found between the three variables: spatial ability and trait anxiety: [F(1, 42) = 0.011, p = .916, η_p^2 = .000]; spatial ability and competition: [F(1, 42) = 0.184, p = .670, η_p^2 = .004]; trait anxiety and competition: [F(1, 42) = 0.029, p = .865, η_p^2 = .001]; spatial ability, trait anxiety and competition: [F(1, 42) = 0.000, p = .994, η_p^2 = .000].

Confidence

A factorial ANOVA showed that competition had a significant effect on confidence, with participants in the competition group showing more confident about their performance than the ones in the control group [F(1, 42) = 5.671, p = .022, η_p^2 = .119]. No effect was found for spatial ability and trait anxiety: spatial ability: [F(1, 42) = 0.525, p = .473, η_p^2 = .012]; trait anxiety: [F(1, 42) = 0.021, p = .885, η_p^2 = .001]. There was also no interaction found between the three variables: spatial ability and trait anxiety: [F(1, 42) = 0.479, p = .493, η_p^2 = .011]; spatial ability and competition: F(1, 42) = 0.026, p = .872, η_p^2 = .001]; trait anxiety and competition: [$F(1, 42) = 0.265$, $p = .609$, $\eta_p^2 = .006$]; spatial ability, trait anxiety and competition: [$F(1, 42) = 2.528$, $p = .119$, $\eta_p^2 = .057$]

5.7 Summary of Results

In summary, the analyses performed showed that map type does have an impact on accuracy and confidence. Participants both performed better and showed more confidence with road maps than with satellite maps, but that map type did not affect the time they took perform the task trials (i.e., response time).

Regarding individual differences, the results revealed that high spatial participants performed better than low spatial ones, and that they also showed more confidence. However, in average, both high and low spatial participants took the same amount of time to perform the task.

The analyses also revealed relevant differences between low and high anxious participants. High anxious participants performed worse than the low anxious ones and showed less confidence regarding their performance, but the two groups did not differ in their response time.

Competition did not show any effect on the participants' performance or response time, but led to an increase of the participants' confidence in their performance.

The results showed that some of the independent variables interact with each other. They revealed that low spatial participants took more time to perform the task when the stimuli were road maps, while their response time did not differ with satellite images. They also reflected a discrepancy between low and high anxious participants regarding their response time in function of map type and competition. Under control conditions, high and low anxious people did not differ in their response time, in any type of map. However, under competition, high anxious participants took significantly more time to answer with road maps than low anxious ones. Response time with satellite images remained similar.

Results did not show any interaction between spatial ability and trait anxiety.

6 Discussion

Investigating the impact of map design, individual differences and environmental conditions in amp information design processing has implications in the Geovisualization field. In general, cartographers must be attentive to create the most suited displays regarding depending on the type of use they are aimed for. Ideally, they should facilitate the understanding and learning of the spatial information they reflect, and to be effective for a large and varied audience. This thesis investigated the effects of map type, spatial ability, and trait anxiety in a route-learning task, under both control and competition conditions. For each of these factors, we summarize and discuss below the main findings of our study. Results are considered with regard to our hypotheses, and limitations of the study are discussed.

6.1 Main Effects of Map type, Spatial Ability, Trait Anxiety and Competition

6.1.1 Road Maps Are more Effective than Satellite Images

The investigation of the effect of map type was particularly motivated by a potential contribution to the abstraction-realism debate. Our general prediction was that map type would not affect performance accuracy or response time on the route-learning task, but that participants would show more confidence with more realistic maps, i.e. satellite images, following the belief that more realism supports understanding (Hegarty et al., 2009).

Contrary to our expectations (Hypothesis 1), our results showed that road maps were more efficient than satellite images to perform a route-learning task. We had predicted that our results would corroborate findings from previous studies that had shown that performance-accuracy was not affected by more realism (Hegarty et al., 2009; Wilkening, 2010). However, our results are consistent with other studies that showed that people are more accurate with simple displays than with enhanced ones (Wilkening & Fabrikant, 2011). The differences between these results obtained in the different studies could be due to differences in the task characteristics and demands. When more time is available to perform the task, more realism does not necessary affect the accuracy of the outcome (e.g., Hegarty et al., 2009). It is also possible tat the task's level of difficulty could also affect performance. It is thus possible that a task involving working memory, as it is the case of the one in our study, requires more cognitive and attentional processing than a road selection task (Jan Wilkening, 2010), and that, therefore, performance is affected only if the task is difficult enough.

As predicted in Hypothesis 2, participants did not significantly differ in their response time in each type of map. However, it must be specified that a time limit was set. Therefore, the possibility exists that the restricted amount of time to answer prompted participants to give a response even if not ready yet for their answer, which might have decreased their accuracy. Importantly, participants were instructed to set accuracy as their main goal, not speed. Therefore, participants might have decided to take more time to be certain about their answers.

Confidence ratings were higher when participants gave their responses to road maps than to satellite maps. This result is not consistent with our prediction (Hypothesis 3), that was based on the assumption of the *Naïve Realism*, that states that people prefer more realism even if it does not increase their performance, and that they would fail to notice impaired performance due to a more realistic display (Smallman & Cook, 2011). However, the fact that participants showed less confidence when their performance was worse suggests that they were able to assess appropriately their own performance, as well as the impairment caused by a more realistic map. In addition, it goes in line with the observed differences in accuracy but not in response time. Thus, a possible interpretation could be that given the time limit, participants may have given quick answers, even if they were less confident with satellite maps, with which they were less accurate.

Therefore, our results identify an interesting link between accuracy and confidence for performance, and indicate that for the kind of task used, map type does affect performance, with road maps being more efficient than satellite images. Task's difference in time limit to answer might explain differences in results across different studies. In agreement with this idea, our results differed from those from (Hegarty et al., 2009). In the latter study, the authors reported that participants took more time to perform the task, but that their performance was no significantly impaired. They suggested that irrelevant information would impose an overload in working memory and thus, require more time to be processed. As in our experiments, participants did not have the supplementary time required to compensate for this potential impairment, it seems logic that accuracy was affected. Importantly, the fact that our results corroborate the findings of Wilkening and Fabrikant's study (2011), in which participants were also confronted to a time limit, supports the view that realism might impair the processing of spatial information.

Hence, our results provide further evidence that more basic displays tend to be more effective and that irrelevant information seems to impose an increased cognitive load, impairing efficient processing (Swienty et al., 2008). On the other hand, our results do not support the assumption specific to *naïve realism*, that users are blinded by their beliefs in realism, and that they cannot recognize a deficit caused by a certain display. Furthermore, our results are not the first to point this accurate self-assessment. In line with our findings, in the slope detection task used by Wilkening and Fabrikant (2011), participants also showed less confidence when their performance was worse.

6.1.2 Spatial Ability Affects Performance independently of Map Type

Classifying participants according to their spatial ability was aimed to confirm the fact that psychometric tests can predict performance on route-learning task. Moreover, this approach was also included in the study to investigate if some types of map could be particularly suitable for low spatial people. We predicted that people who had previously scored poorly at the mental rotation test would perform worse than high spatial people in the task, with both types of map, and that they would require more time to accomplish the task, since it was supposed to represent a bigger challenge for them. We also predicted that they would be aware of their difficulty, and thus, show less confidence than high spatial participants.

Consistent with our predictions and with several previous studies (e.g, Pazzaglia & Beni, 2006; Wilkening & Fabrikant, 2011), high spatial participants performed significantly better than low spatial people with both types of maps (Hypothesis 4). This result suggest that the Vandenberg Mental Rotation test is suited to predict performance in a route-learning task involving learning through media (Hegarty et al., 2006). One possible reason for this results might be related to the fact that the task included working memory, as this cognitive process has been closely linked to spatial ability, and especially to *Spatial Visualization* (Miyake et al., 2001).

On the other hand, we found that response time did not differ between low and high spatial participants. Although this result is contrary to our hypothesis (Hypothesis 5), it is probably explained by the set time limit, that prompted the participants to give an answer within the time limit.

Regarding confidence ratings, the results corroborate our expectations (Hypothesis 6), with low spatial participants being less confident in their performance than high spatial ones. Furthermore, they showed less confidence in their performance with satellite maps than with the road maps. Interestingly, these results differ from the study of (Smallman & Cook, 2011), in which low spatial people were found to be unable to readjust their preference to their actual performance on a terrain understanding task.

Therefore, this set of results confirms that psychometric tests can predict performance on a media based learning task, with low scores predicting worse performance. However, the fact that confidence follows performance accuracy for low spatial ones as much as high spatial ones suggest that low spatial people, in addition of being aware of the difficulty they face, are not blinded by the belief that more realism is more efficient. Again, these results question the assumption of *Naïve Realism* theory, which assumes that preference for enhanced realism is maintained after having performed poorly at a task involving a more realistic display.

6.1.3 Trait Anxiety Affects Performance and Confidence

By investigating the effect of trait anxiety in a spatial task, this study aimed at extending the scope of research addressing individual differences in Geovisualization. Our main predictions were that high anxious participants would perform similarly to low anxious in terms of accuracy (under normal condition), but that they would require more time to complete the trials. We also predicted that high anxious people would report less confidence than low anxious ones, as worry would affect their self-confidence.

Contrary to our predictions, high anxious participants were less accurate than low anxious ones for the task under basal, control conditions (Hypothesis 7). This result is not consistent with some previous research reporting similar accuracy between different anxiety levels in working-memory tasks (e.g. Eysenck, 1985). On the other hand, some studies have reported that anxiety affects visuospatial working memory in a larger extent than verbal working memory (Vytal et al., 2013). Hence, differences in the type of information processing engaged in working memory could be the cause of the difference in results.

Concerning response time, our results do not support a key prediction based on the Attention Control Theory (Eysenck et al., 2007), according to which anxiety would lead to an increase in response time instead of affecting accuracy when performance take place under normal, basal, environmental conditions (Hypothesis 8). In our study, low and high anxious participants took the same time to answer the trials. However, we must stress the fact that the imposed time limit might be the reason for the similar response time found in the two groups, and could also be responsible for our finding of decreased accuracy instead of efficiency in high anxious participants. As discussed when comparing the similar response times for different map types in the two spatial ability groups (Sections 6.1.1 and 6.1.2), the short amount of time available to give an answer probably prompted participants to answer even if they were not sure of their response. In this sense, out results support the Processing Efficiency Theory (Eysenck & Calvo, 1992). Accordingly, the time limit could have prevented high anxious people from increasing their mental effort, impairing their performance.

Regarding confidence, consistent with our hypothesis, high anxious participants reported less confidence than low anxious ones (Hypothesis 9). The role of anxiety in this result, however, is not known. Probably, given that our results showed that confidence follows performance, lower confidence might in fact reflect that high anxious people are, as well as low anxious ones, capable to assess their performance.

Therefore, in general, our results support the Attention Control Theory (Eysenck et al., 2007), with high anxious participants performing worse than low anxious ones, as they are not able to cope with their difficulties (e.g., by enhancing mental effort). Our results also suggest that alternative strategies to cope with high information processing load were prevented due to the pre-set time limit; hence accuracy was affected instead of response time. Our results also revealed that high anxious participants were less confident than low anxious participants. However, it is unclear to what extent anxiety affected this variable, as confidence ratings matched accuracy performance and, thus, reduced confidence in high anxious participants might be derived from a primary effect of anxiety in accuracy.

6.1.4 Competition Affects Confidence

Introducing competition was aimed to investigate if a relevant change in environmental conditions could affect performance on the task. We predicted that, under competition, participants would increase their effort and, hence increase their performance. We also expected that they would complete the task faster and that their confidence will be enhanced.

Contrary to our hypotheses, participants' performance in the competition group did not differ from the ones in the control group (Hypothesis 10). These results revealed the competition manipulation did not improve performance. One possible explanation is that participants were already performing at best under control conditions, which would prevent enhancing accuracy by external manipulations (i.e. a ceiling effect). It is important to note that the task was developed for this study and, therefore, there was no previous data to establish comparison with performance in previous studies.

Furthermore, also contrary to our prediction, participants in both control and competition conditions did not differ in their response time (Hypothesis 11). This can be explained by different reasons. First, in the competition condition, they were explicitly told that the winner will be determined in function of his accuracy scores, response time only counting if there were more than one wining participants with equal accuracy scores. Logically, participants probably focused on being accurate rather than on being fast. Second, the pre-set time limit was long enough to complete the task, but did not provide a big margin.

Surprisingly, reported self-confidence was significantly higher in the competition group than in the control group, even if their performance in accuracy or response time was not improved (Hypothesis 12). An increase in confidence was predicted based on the assumption that confidence would follow performance. However, these results are clearly related to a complex link between competition and confidence that is unknown to us.

Therefore, this set of results revealed that participants under competition showed more confidence, although their performance in accuracy or in response time was not affected. These findings are in contrast with previous research that has shown improved performance due to competition (e.g. Bandura & Cervone, 1983; Cooke et al., 2011). A possible reason is that the working memory nature of the task might have posed difficulties for improved performance. Confidence increased with competition, supporting results of previous studies (e.g., Butt et al., 2003), but the fact that is was not accompanied by improved performance differs from studies that have reported confidence as an important predictor for enhanced performance under competition (Bandura & Cervone, 1983; Parfitt & Pates, 1999). However, we should note that confidence measurements in those studies referred to the subjects' expectations towards their subsequent performance in the task, whereas in ours it reflects the certainty participants had regarding the accuracy of their responses immediately after their performance in each trial.

6.2 Interaction between factors

6.2.1 Spatial Ability and Trait Anxiety do not Interact

Our results revealed no evidence of interaction between spatial ability and trait anxiety. Despite the fact that working memory is strongly linked with spatial ability and trait anxiety, our results show that the two variables have a separate impact.

Several studies have presented evidence supporting the link between trait anxiety and executive function (Eysenck et al., 2007), especially with the inhibition function and the shifting function. Executive functioning was also linked to spatial abilities, particularly *Spatial Visualization* (Miyake et al., 2001), which was found predictive of performance in our study. Attention control theory, however, assumes that the phonological loop is more likely to be affected by anxiety than the visuospatial sketchpad, worry involving "inner verbal activity rather than imagery representations" (Eysenck et al., 2007, p. 337). On the other hand, in addition of being highly linked with executive function, spatial abilities are also determined by visuospatial storage, hence the visuospatial sketchpad (Miyake et al., 2001). The fact that distribution of trait anxiety within high and low spatial groups and the other way was not significantly different supports both these two explanations.

6.2.2 Interaction between Spatial Ability and Map type

Our results showed that low and high spatial participants performed better, and were more confident, with road maps than with satellite images, further indicating that for both low an high spatial people, more realistic displays might represent an overload of information, leading to impaired performance. The fact that both low and high spatial participants showed more confidence with road maps than satellite maps suggest that high and low people might be able to notice impaired performance due to more realistic displays.

However, an interaction was found concerning response time (Hypothesis 13). High spatial people did answer significantly faster than low spatial people when the stimuli were road maps, but not when they were presented aerial images. More realistic displays require more time to process the supplementary information, whereas high spatial participants show an advantage versus low spatial ones in the processing of the simpler roadmaps.

6.2.3 Interaction between Spatial Ability and Competition

Initially, we had no hypothesis concerning the interaction between spatial ability and competition, and none was found. Under competition, high and low participants did not differ in their accuracy, suggesting that the task was too difficult to mobilize additional resources, even for high spatial participants. The two groups also did not differ in their response time, but both showed an increase in confidence.

6.2.4 Trait Anxiety and Map Type do not Interact

Initially, we had as hypothesis an interaction between trait anxiety and map type would be revealed with high anxious participants being slower than low anxious ones to answer with satellite maps (Hypothesis 14), but none was found. In general, both low and high anxious participants performed better with road maps than satellite maps, and took similar time to answer the trials independently of map type stimuli. Map type did not affect interact with anxiety for the confidence ratings either.

6.2.5 Interaction between Trait Anxiety and Competition

Competition was initially introduced in order to challenge individuals differing in trait anxiety. Since change in environment conditions can affect anxiety, we expected that negative effects of anxiety would be revealed under competition condition, by affecting performance in response time and in accuracy (Hypothesis 15).

However, our results showed no difference in performance between low and high anxious people under the different conditions. As a difference in performance was revealed between low and high anxious participants in basal conditions, these results are not surprising. They suggest that the condition that we defined as control might have already contained stressful elements, and therefore, high anxious participants' cognitive resources were already challenged. Nevertheless, our results revealed that with road maps, low anxious people responded faster under competition. However, high anxious people did not improve their response type, with any of the two map types, which suggest that indeed, their cognitive resources might have already been exploited to a maximum, and thus, supporting the Attention Control Theory (Eysenck et al., 2007).

Interestingly, both low and high anxious participants reported higher confidence during competition. This result suggests that confidence is not affected by worry, as was proposed above for the discussion of the difference in confidence found between low and high anxious participants (see Section 6.1.3), but rather that high anxious participants were able to assess their performance just as much as low anxious ones. Even more interesting, the stress induced through competition did not affect their self-confidence, but in the contrary, it enhanced it. This suggests that the act of the potential increased engagement in the task elicited by the competition condition might be enough to over-evaluate self-efficacy.

6.3 Study Limitations

This thesis is embedded in the *Naïve Realism* debate. We measured task accuracy and response time for realistic satellites images and for more abstract road maps, with the aim to compare performance regarding to differences in realism. In addition, self-confidence ratings were gathered, which helped to determine if participants were aware of their accuracy level in the task for each of the to map types. However, we did not gather any information about their preferences, which would have allowed us to addressing the theory for all its key assumptions and to better compare our results with previous research within the debate.

One of the important points to mention is that we defined a time limit to give the answer for each trial, as we needed to control the length of experimental sessions in which participants were engaged for one hour. However, this time limit has probably played the role of a stressor even under the experimental conditions considered as control, or basal, without additional competition. The time interval set to give the answer in each trial was probably not long enough to reveal important variability, and thus, it prevented us from addressing one key assumption of the Processing Efficiency Theory (Eysenck et al., 2007), i.e. that although trait anxious people are usually able to perform a task, they require to pull some extra resources to reach the same level of accuracy than low anxious people. Hence, the results of this study concerning time should be considered under the notion of the imposed time pressure.

Although time limit might have worked as a stressor, the proposition of a reward for the winner has probably served as an incentive, as differences in cortisol levels and confidence ratings between the control and the competition group. Participants were not given their score after the first block of trials. Hence, when entering into competition, it was maybe more difficult for them to readjust their standards to improve their performance. Optimal competition condition would maybe been have been reached with clear feedbacks on the participants' performance, as it was determined as an important setting for competition, and the related increase of effort (Stanne et al., 1999).

7 Conclusion and Implications for Further Research

This thesis investigated the role of road versus satellite maps in a route-learning task involving working memory and aimed to provide material for current research in Geovisualization, especially regarding abstraction-realism debate and individual differences, but also by addressing the potential impact of a change in environmental conditions.

Our results have reported a higher performance with road maps than with satellite maps, suggesting that for such a task, task-irrelevant information contained in more realistic displays impose an increased cognitive load impairing performance (Swienty et al., 2008). Interestingly, more realistic satellite maps impaired high spatial participants' performance as much as the one of low spatial ones. Accordingly, our findings provide some further evidence to support more abstract design for cognitively-demanding tasks and give credit to basic cartographic principles (Bertin & Barbut, 1967). By asking our participants to report their confidence in their own performance, our work joins up with the *Naïve Realism* debate (Hegarty et al., 2009; Smallman & John, 2005). We found that unlike a key assumption in existing theory, stating that people are not able to choose what is best for them, even after having experienced an impaired performance with more realistic maps, our participants were less confident in their performance when they answered with satellite maps. These findings, together with similar ones in a study by Fabrikant and Wilkening (2011), suggest that the assumptions of *Naïve Realism* must be further investigated with regard to the type of task and the cognitive processes they involve. Furthermore, our results suggest that low spatial people might be able to notice an impaired performance due to a loaded display as much as high spatial people. Together, these finding highlight the importance of designing suitable displays, and to avoid enhanced representations to meet users' preferences, that might impair their performance. While our results do suggest that users might be able to assess the effectiveness of a display, independently of their spatial ability, this can only occur if comparison is possible. Hence, people might still choose a more realistic display when alternatives are available. Thus, attention must be paid to the varieties of displays proposed to the user, and maybe information concerning the best-suited type of map for which kind of task should be made available.

A second axis of interest in our study was to explore the role of individual differences in a geographical task. In addition to addressing spatial ability, trait anxiety was introduced as a potential factor influencing performance in a route-learning task. Our findings have shown that participants scoring low at the Vandenberg Mental Rotation test (Vandenberg & Kuse, 1978) performed worse compared to high scoring participants, indicating that psychometric tests can be good predictors for a media-based learning task involving visuospatial memory. Low spatial participants also reported less confidence than high spatial people. The fact that confidence matched performance in low and high spatial participants suggests that high and low spatial people are equally capable of self-assessment regarding their performance, as well as high spatial ones. Our results indicate that trait anxiety is a relevant variable to address learning and information processing discrepancies among individuals. We found that high anxious participants performed worse and showed less confidence than low anxious ones, suggesting that under time pressure, the former are not able to mobilize enough resources to cope with their difficulty to select relevant information for the task.

Furthermore, although spatial ability and trait anxiety are closely related to working memory, our findings have revealed that they have a differentiated impact on the task. Otherwise stated, high anxious people can have variable spatial ability. Importantly, this suggests that focus on spatial ability does not reflect a global aspect of how individuals differ in their way to learn and to process information. Hence, our findings indicate that research in Geovisualization should embrace a larger scope of approaches when addressing individual differences.

In addition to investigating the role of realism in maps, spatial ability and trait anxiety, our work also addressed the question of the environmental context in which the task is performed. Surprisingly, our results revealed that participants in the competition group reported higher confidence than the ones in the control group, even if their accuracy or response time did not change. These results stress an interesting relation between competition and confidence that deserves more investigation, especially for the implications overconfidence can have in real-life situations.

Together, our findings indicate practitioners should design more abstract maps and avoid task-irrelevant information in their displays, but also promote efforts to increase awareness in the users when choosing between a variety of displays. It also argues Geovisualization research should embrace new approaches to understanding how individuals learn, in order to enhance our insight into the construction of knowledge.

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Appendix A. Online Questionnaire

A.1 Demographic Questionnaire

Quelle est votre langue maternelle?

- ○ Anglais
- ○ Espagnol
- ○ Chinois
- ○ Français
- ○ Allemand
- ○ Arabe
- ○ Japonais
- ○ Hébreu
- ○ Suédois
- ○ Autre (prière de spécifier) ________

Quel est votre sexe?

- ○ Femme
- ○ Homme

Qu'est-ce qui décrit au mieux la région dans laquelle vous vivez?

- ○ Région urbaine
- ○ Région suburbaine
- ○ Région rurale

Quel est le niveau de revenu du ménage dans lequel vous vivez?

- ○ moins de 5'000 francs par an
- ○ entre 5'000 francs et 10'000 francs par an
- ○ entre 10'000 francs et 15'000 francs par an
- ○ entre 15'000 francs et 20'000 francs par an
- ○ entre 20'000 francs et 30'000 francs par an
- ○ entre 30'000 francs et 50'000 francs par an
- ○ entre 50'000 francs et 80'000 francs par an
- ○ entre 80'000 francs et 120'000 francs par an
- ○ entre 120'000 francs et 160'000 francs par an
- ○ plus de 160'000 francs par an

A. 2. State Trate Anxiety Inventory (STAI - T)

Un certain nombre de phrases que l'on utilise pour se décrire sont données ci-dessous. Lise chaque phrase, puis sélectionnez parmi les quatre possibilité, celle qui correspond le mieux à ce que vous ressentez GENERALEMENT. Il n'y a pas de bonnes ni de mauvaises réponses. Ne passez pas trop de temps sur l'une ou l'autre de ces propositions et indiquez la réponse qui décrit le mieux vos sentiments HABITUELS.

	Presque jamais	Parfois	Souvent	Presque toujours
Je me sens de bonne humeur, aimable.	○	○	○	○
Je me sens nerveux (nerveuse) et agité(e)	○	○	○	○
Je me sens content(e) de moi.	○	○	○	○
Je voudrais être aussi heureux (heureuse) que les autres semblent l'être.	○	○	○	○
J'ai un sentiment d'échec.	○	○	○	○
Je me sens reposé(e).	○	○	○	○
J'ai tout mon sang-froid.	○	○	○	○
	Presque jamais	Parfois	Souvent	Presque toujours
J'ai l'impression que les difficultés s'accumulent à un tel point que je ne peux plus les surmonter.	○	○	○	○
Je m'inquiète à propos de choses sans importance.	○	○	○	○
Je suis heureux(se).	○	○	○	○
J'ai des pensées qui me perturbent.	○	○	○	○
Je manque de confiance en moi.	○	○	○	○
Je me sens sans inquiétude, en sécurité, en sûreté.	○	○	○	○
Je prends facilement des décisions.	○	○	○	○
	Presque jamais	Parfois	Souvent	Presque toujours
Je me sens incompétent(e), pas à la hauteur.	○	○	○	○
Je suis satisfait(e).	○	○	○	○
Des idées sans importance trottant dans ma tête me dérangent.	○	○	○	○
Je prends les déceptions tellement à coeur que je les oublie difficilement.	○	○	○	○
Je suis une personne posée, solide, stable.	○	○	○	○
Je deviens tendu(e) et agité(e) quand je réfléchis à mes soucis.	○	○	○	○
	Presque jamais	Parfois	Souvent	Presque toujours

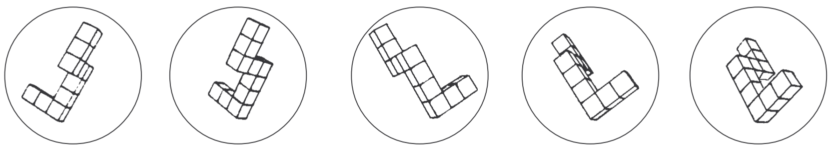
A.3. Vandenberg Mental Rotation Test

ANNEXE

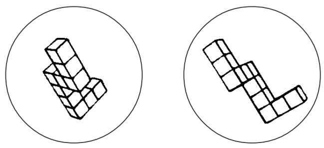
Test de rotation mentale

adapté par S.G. Vandenberg, université du Colorado, 1971
consignes révisées par H. Crawford, université du Wyoming, 1979
traduction française par J.M. Albaret et E. Aubert, 1990

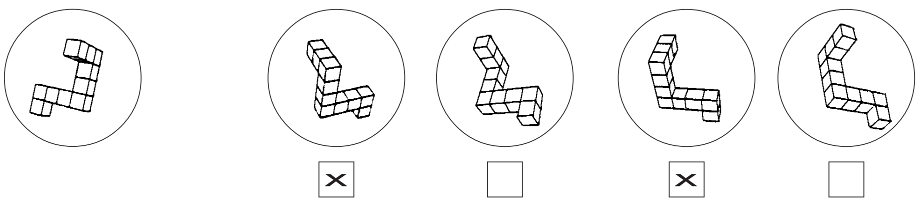
"Ceci est un test destiné à mesurer votre aptitude à reconnaître le dessin d'un objet donné parmi un ensemble d'objets différents. La seule différence entre l'objet original et l'objet à trouver consiste en une modification de l'angle sous lequel il est vu. Une illustration de ce procédé est donnée ci-dessous, où la même figure est présentée dans cinq positions. Regardez chacun d'entre eux pour vous rendre compte vous-même qu'ils sont seulement présentés sous un angle différent l'un de l'autre."



"Ci-dessous, vous voyez deux dessins d'un nouvel objet. Ils ne peuvent pas être appariés avec les cinq dessins ci-dessus. Notez que vous ne pouvez pas retourner les objets. Voyez vous-mêmes qu'ils sont différents."



"Maintenant, vous allez faire quelques problèmes en guise d'exemple. Pour chaque problème il y a un premier dessin tout à fait à gauche. Vous devez indiquer parmi les quatre structures à droite, les deux qui sont semblables au modèle donné à gauche. Dans chaque problème, il y a toujours deux dessins semblables à celui de gauche. Mettez un x dans les cases sous les dessins corrects et laissez un blanc dans celles qui sont incorrectes. Le premier exemple est déjà complété."



"Tournez la page."

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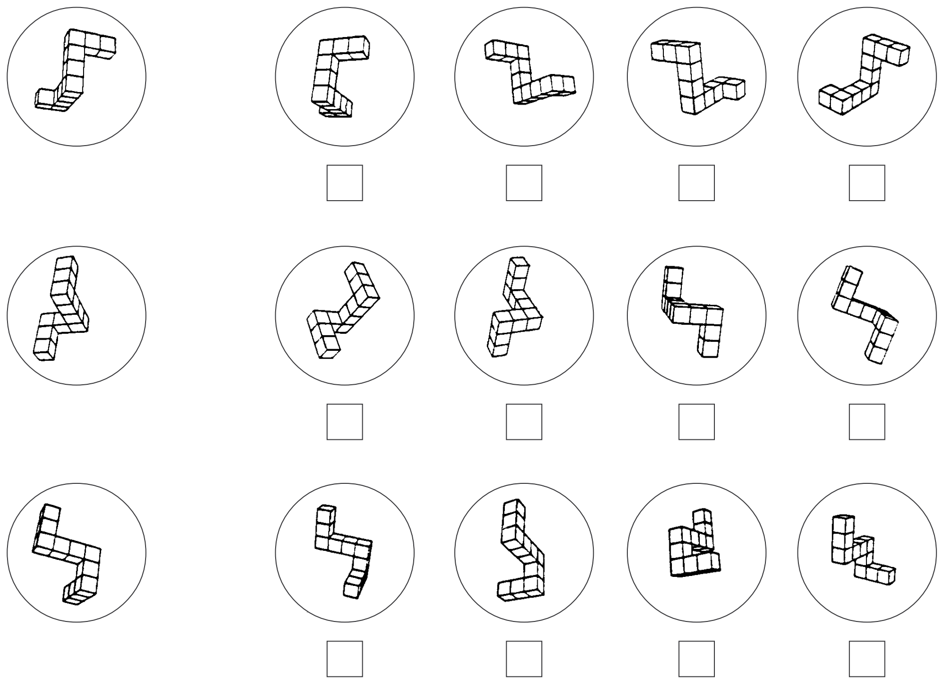
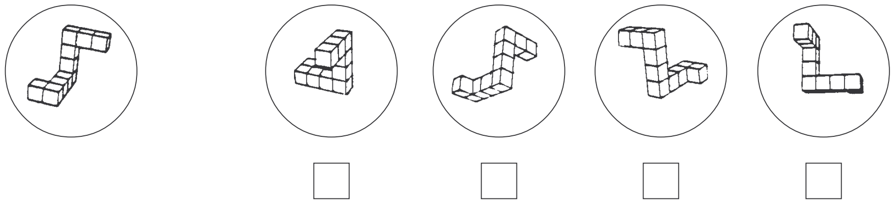
Complétez les exemples suivants vous-même. Quels sont les deux dessins, parmi les quatre situés à droite, qui montrent la même structure que celle de gauche ? Il y a toujours deux et seulement deux réponses correctes pour chaque problème. Mettez un x sous les deux dessins corrects.” *(3 exemples à compléter, puis à corriger immédiatement).*

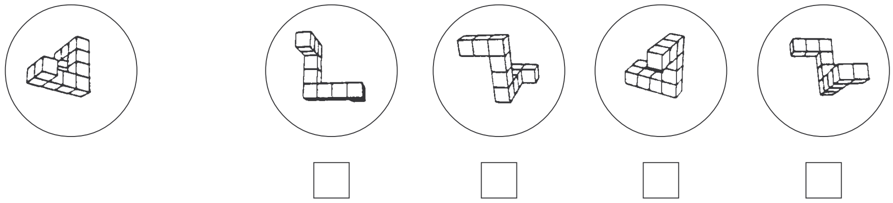


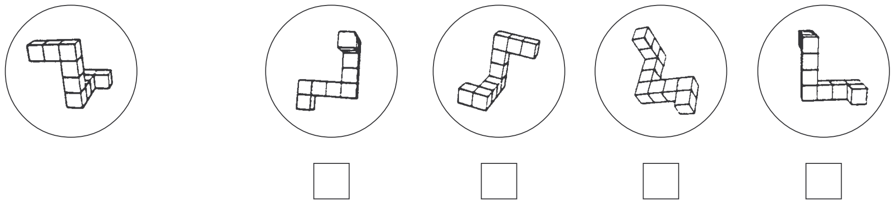
“Réponses : 1 - Premier et second dessins corrects
2 - Premier et troisième dessin corrects
3 - Deuxième et troisième dessins corrects

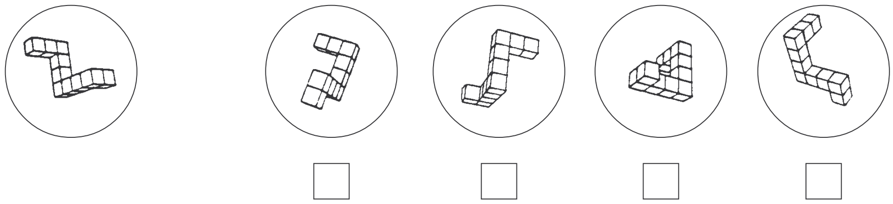
Ce test comprend deux parties. Vous avez 3 minutes pour chacune. Chaque partie a deux pages. Quand vous avez fini la partie 1, arrêtez-vous. Ne commencez pas la partie 2 avant d’en être prié. Rappelez-vous qu’il y a toujours deux et seulement deux réponses correctes par item. Travaillez aussi rapidement que vous pouvez sans négliger l’exactitude. Votre score à ce test dépend à la fois des réponses correctes et incorrectes. Cependant, vous n’avez pas intérêt à deviner sans avoir une idée sur l’exactitude de votre choix.

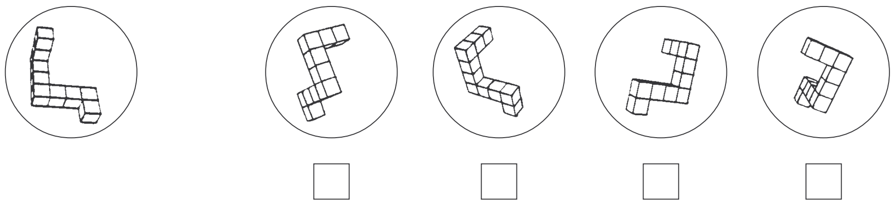
Ne tournez pas la page avant le signal.

1 

2 

3 

4 

5 

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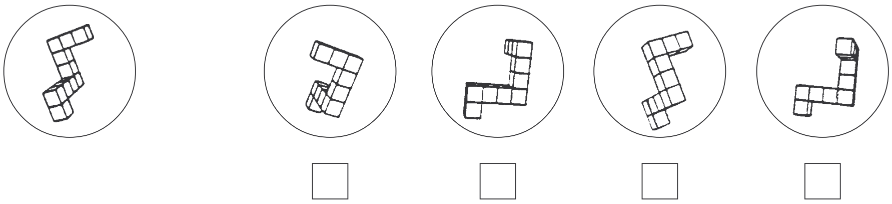

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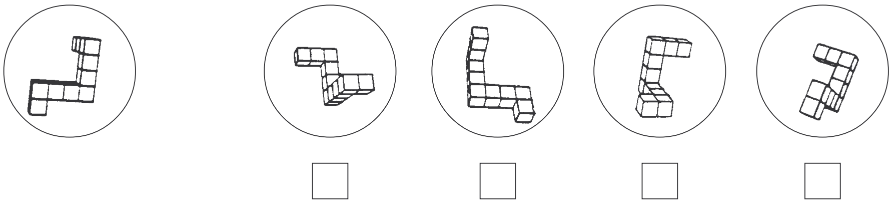

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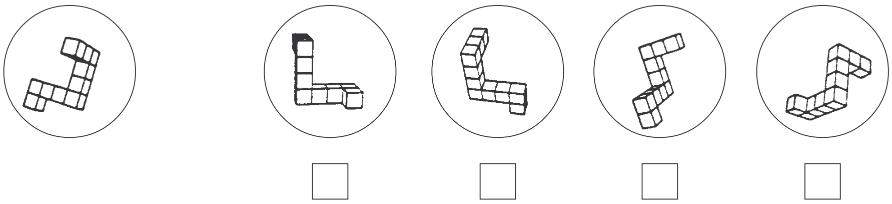

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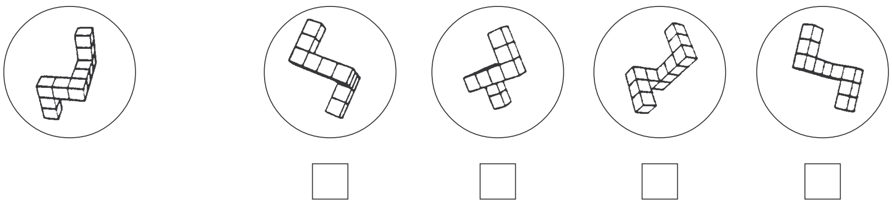

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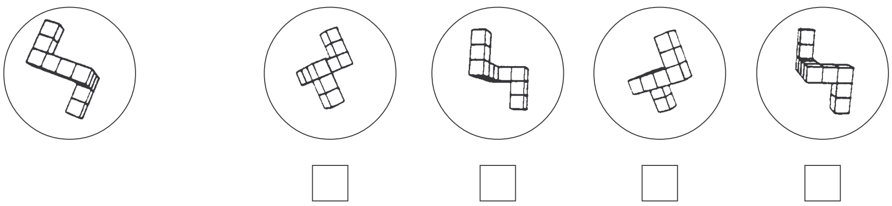

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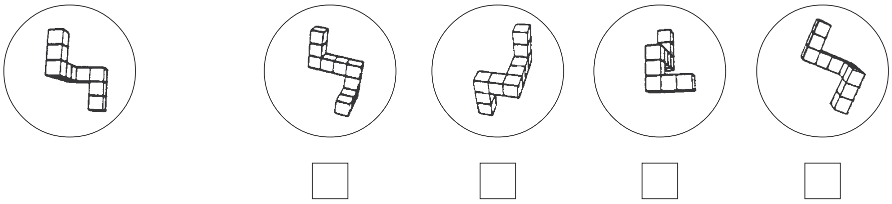

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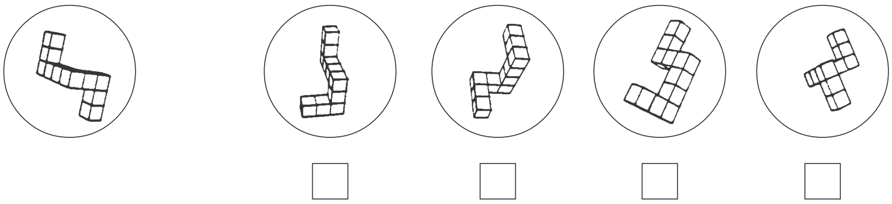

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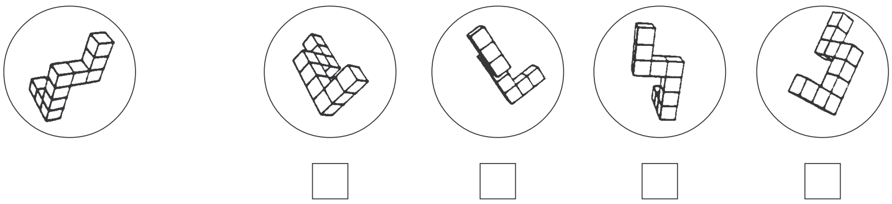

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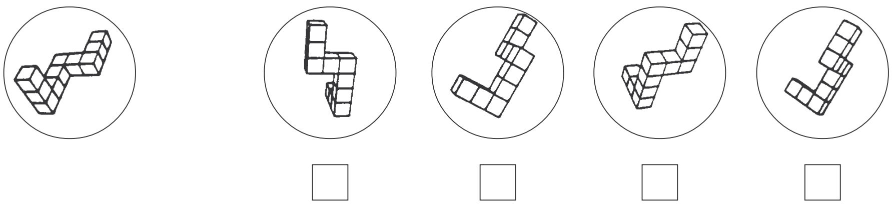

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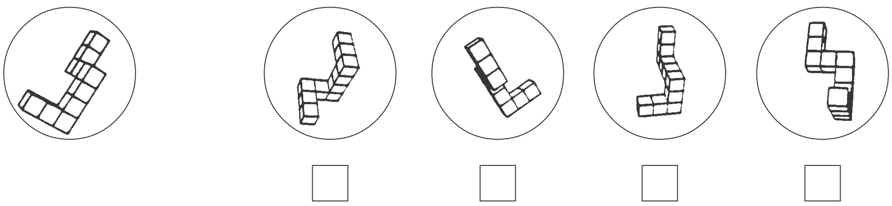

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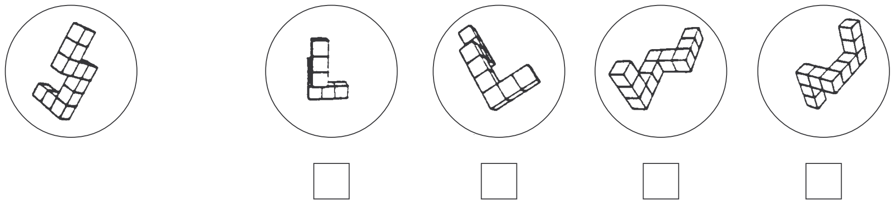
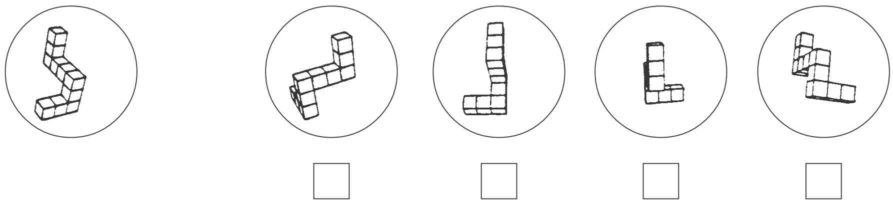
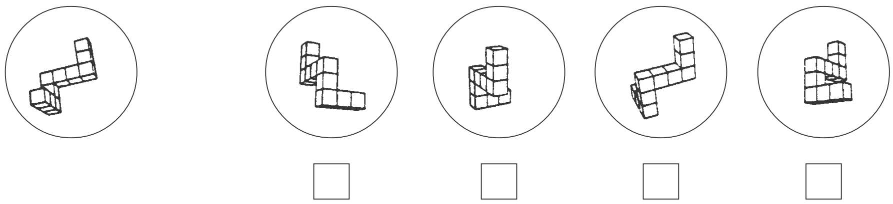
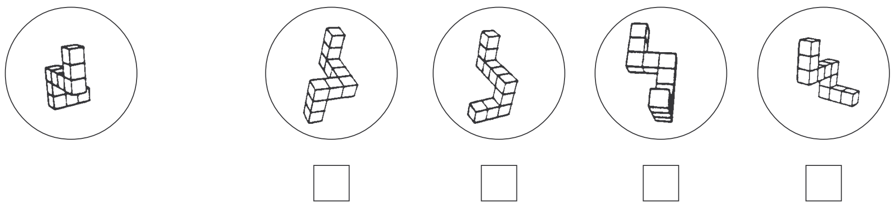
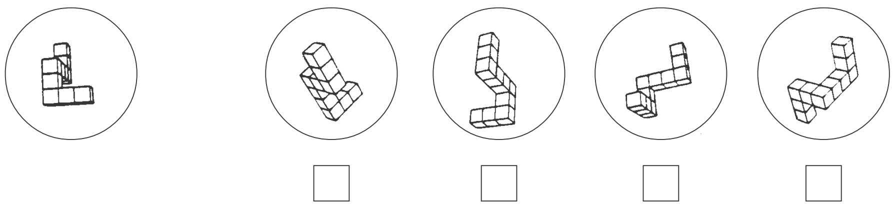
16 

17 

18 

19 

20 

STOP

Appendix B. Participants Booklet

BRAIN MIND INSTITUTE - BMI
LABORATORY OF LGC

EPFL-SV-BMI-LGC
Station 19
CH-1015 Lausanne - Switzerland

Phone : 021 693 7261
E-mail : john.thoresen@epfl.ch
Website : lgc.**epfl**.ch

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

NOTICE D'INFORMATION AUX PARTICIPANTS A UN PROJET DE RECHERCHE

Titre de l'étude: **Navigation, orientation et différences individuelles**.

Vous êtes invité à participer à une étude comportementale sur l'apprentissage de routes.

La participation à cette expérience comprend deux étapes : Etape 1 : Nous vous demanderons de compléter une série de questionnaires en ligne, qui durera environ 30 minutes. Etape 2: Ensuite, nous vous demanderons de participer à une séance expérimentale à L'EPFL; cette séance durera environ une heure. Au cours de cette session, nous vous demanderons de nous fournir des échantillons de salive pour des analyses d'hormones. Il s'agit d'une procédure standard: les échantillons seront traités au sein de notre laboratoire avec prudence et resteront anonymes.

Il n'y a aucun risque physique associé à la participation à cette étude. Vous êtes libre d'interrompre votre participation à n'importe quel moment et vous pouvez demander à ce que vos données soient détruites sans nous donner le moindre justificatif et sans que cela ne vous porte le moindre préjudice. Vos données seront traitées de façon confidentielle et seront rendues anonymes. Ainsi, à l'issue de l'expérience, personne ne pourra faire le lien entre vous et les données que nous avons collectées. Les vidéos ne seront accessibles qu'aux collaborateurs de l'étude et ne seront jamais montrées à des personnes extérieures.

Vous êtes invité à nous demander toute clarification nécessaire ou toute information complémentaire. La décision de participer ou non au projet vous revient. Le fait de ne pas participer ne vous désavantagera pas. En tant que participant, vous avez le droit de vous retirer du projet à tout moment, sans aucune conséquence négative pour vous.

Toutes les données traitées dans le cadre du projet de recherche seront collectées et sauvegardées de manière sécurisée et anonyme, conformément à la Loi fédérale sur la protection des données (RS 235.1). Seuls le chercheur principal et/ou les membres du Comité d'éthique de la recherche humaine de l'EPFL auront accès aux données originales, et seront soumis à une obligation de stricte confidentialité.

Un éventuel dommage à votre santé, directement causé par le projet de recherche ci-dessus et découlant manifestement d'une faute de l'EPFL, est couvert par l'assurance responsabilité civile de l'EPFL (police d'assurance N° 30/5.006.824 de Bâloise Assurances). Cependant, dans tout autre cas, il est de votre responsabilité de conclure une assurance maladie et accident.

Comp.

!This page is not integrated in control participants booklet!

PROF. CARMEN SANDI
EPFL
BRAIN MIND INSTITUTE

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Formulaire de consentement éclairé

Titre de l'étude : Navigation, orientation et différences individuelles.

Le/La soussigné(e):

- Certifie avoir été informé sur le déroulement et les objectifs de l'étude ci-dessus.

- Affirme avoir lu attentivement et compris les informations écrites fournies dans le document *Information pour les Volontaires*, informations à propos desquelles il a pu poser toutes les questions qu'il souhaitait.
- Certifie avoir été informé des avantages et des risques éventuels qui sont associés à cette étude et des obligations qui lui incombent pour cette participation à cette étude.

- Atteste qu'un temps de réflexion suffisant lui a été accordé.

- A été informé du fait qu'il pouvait interrompre à tout instant sa participation à cette étude sans préjudice d'aucune sorte.

- Autorise de contactes par email pour m'informer des autres études ou de me demander plus d'informations.

- Consent à ce que les données recueillies pendant l'étude puissent être transmises à des personnes extérieures (publications scientifiques), la confidentialité de ces informations étant sauvegardée.

- Affirme avoir été informé(e) qu'un éventuel dommage à ma santé, directement causé par le projet de recherche ci-dessus et découlant manifestement d'une faute de l'EPFL, est couvert par l'assurance responsabilité civile de l'EPFL (police d'assurance N° 30/5.006.824 de Bâloise Assurances). Cependant, dans tout autre cas, il est de ma responsabilité de conclure une assurance maladie et accident

Le soussigné accepte donc de participer à l'étude mentionnée dans l'en-tête.

Nom, prénom et signature du patient/volontaire: ....

....

Date: ....

Nom et coordonnées du responsable de l'étude:

john.thoresen@epfl.ch
LGC – BMI, SV, EPFL

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Instructions

Un certain nombre de phrases que l'on utilise pour se décrire sont données ci-dessous. Lisez chaque phrase, puis marquez d'un cercle, parmi les quatre chiffres à droite, celui qui correspond le mieux à ce que vous ressentez **à l'instant, juste en ce moment**. Il n'y a ni bonnes ni mauvaises réponses. Ne passez pas trop de temps sur l'une ou l'autre de ces propositions, et indiquez la réponse qui décrit le mieux vos sentiments actuels.

1	**2**	**3**	**4**
Non	**Plutôt non**	**Plutôt oui**	**Oui**

1. Je me sens calme. ……………………………………..	**1**	**2**	**3**	**4**
2. Je me sens en sécurité, sans inquiétude, en sûreté...……	**1**	**2**	**3**	**4**
3. Je suis tendu(e), crispé(e)………………………………	**1**	**2**	**3**	**4**
4. Je me sens surmené(e)………………………………….	**1**	**2**	**3**	**4**
5. Je me sens tranquille, bien dans ma peau………………	**1**	**2**	**3**	**4**
6. Je me sens ému(e), bouleversé(e), contrarié(e)………..	**1**	**2**	**3**	**4**
7. L'idée de malheurs éventuels me tracasse en ce moment………………………………………..	**1**	**2**	**3**	**4**
8. Je me sens content(e)………………………………...	**1**	**2**	**3**	**4**
9. Je me sens effrayé(e)……………………………………	**1**	**2**	**3**	**4**
10. Je me sens à mon aise…………………………………..	**1**	**2**	**3**	**4**
11. Je sens que j'ai confiance en moi………………………	**1**	**2**	**3**	**4**
12. Je me sens nerveux (nerveuse), irritable………………..	**1**	**2**	**3**	**4**
13. J'ai la frousse, la trouille………………………………..	**1**	**2**	**3**	**4**
14. Je me sens indécis(e)……………………………………	**1**	**2**	**3**	**4**
15. Je suis décontracté(e), détendu(e)………………………	**1**	**2**	**3**	**4**
16. Je suis satisfait(e)……………………………………….	**1**	**2**	**3**	**4**
17. Je suis inquiet, soucieux (inquiète, soucieuse)………….	**1**	**2**	**3**	**4**
18. Je ne sais plus où j'en suis, je me sens déconcerté(e) dérouté(e)…………………………………………….	**1**	**2**	**3**	**4**
19. Je me sens solide, posé(e), pondéré(e), réfléchi(e)……...	**1**	**2**	**3**	**4**
20. Je me sens de bonne humeur, aimable…………………..	**1**	**2**	**3**	**4**

STOP !

Ne tournez pas la page avant que l'on vous le demande.

! This page is not integrated in control participants booklet!

Partie 2

Merci de ne pas lire ce texte avant que l'on vous le demande.

Vous venez de compléter la partie d'exercice.

Pendant la tâche, on vous a donné votre score en pourcentage. Veuillez maintenant indiquer quel rang vous croyez avoir obtenu par rapport aux autres participants dans cette salle :

____________ (1, 2, 3 ou 4)

Maintenant, vous auriez à entrer dans une compétition avec les autres participants dans cette salle pendant une tâche similaire à celle que vous venez de faire. La personne qui touche le score le plus élevé va gagner une somme outre le dédommagement prévu (**25 francs garanti**). Cette somme sera calculée en fonction d'un jet de dés. Nous prenons le résultat du jet (entre 1 et 6) et on multiplie par 5 francs. Ainsi, vous pouvez gagner entre **5 et 30 francs supplémentaire**.

Votre score sera aussi comparé avec toutes les personnes qui participent à cette expérience (au cours des mois d'octobre et novembre, 2013). La personne avec le score le plus élevé gagnera **50 francs davantage**. Vous seriez informé par mail avant le 15 novembre si vous avez gagné.

Si deux personnes ont obtenu le même score, nous comparerons le délai des réponses : ainsi, celui qui a été le plus rapide (en moyenne) a gagné.

Merci d'attendre les instructions de l'expérimentateur/l'expérimentatrice.

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Instructions

Un certain nombre de phrases que l'on utilise pour se décrire sont données ci-dessous. Lisez chaque phrase, puis marquez d'un cercle, parmi les quatre chiffres à droite, celui qui correspond le mieux à ce que vous ressentez **à l'instant, juste en ce moment**. Il n'y a ni bonnes ni mauvaises réponses. Ne passez pas trop de temps sur l'une ou l'autre de ces propositions, et indiquez la réponse qui décrit le mieux vos sentiments actuels.

1	**2**	**3**	**4**
Non	**Plutôt non**	**Plutôt oui**	**Oui**

1. Je me sens calme. ……………………………………..	**1**	**2**	**3**	**4**
2. Je me sens en sécurité, sans inquiétude, en sûreté...……	**1**	**2**	**3**	**4**
3. Je suis tendu(e), crispé(e)………………………………	**1**	**2**	**3**	**4**
4. Je me sens surmené(e)………………………………….	**1**	**2**	**3**	**4**
5. Je me sens tranquille, bien dans ma peau………………	**1**	**2**	**3**	**4**
6. Je me sens ému(e), bouleversé(e), contrarié(e)………..	**1**	**2**	**3**	**4**
7. L'idée de malheurs éventuels me tracasse en ce moment………………………………………..	**1**	**2**	**3**	**4**
8. Je me sens content(e)………………………………...	**1**	**2**	**3**	**4**
9. Je me sens effrayé(e)……………………………………	**1**	**2**	**3**	**4**
10. Je me sens à mon aise…………………………………..	**1**	**2**	**3**	**4**
11. Je sens que j'ai confiance en moi………………………	**1**	**2**	**3**	**4**
12. Je me sens nerveux (nerveuse), irritable………………..	**1**	**2**	**3**	**4**
13. J'ai la frousse, la trouille………………………………..	**1**	**2**	**3**	**4**
14. Je me sens indécis(e)……………………………………	**1**	**2**	**3**	**4**
15. Je suis décontracté(e), détendu(e)………………………	**1**	**2**	**3**	**4**
16. Je suis satisfait(e)……………………………………….	**1**	**2**	**3**	**4**
17. Je suis inquiet, soucieux (inquiète, soucieuse)………….	**1**	**2**	**3**	**4**
18. Je ne sais plus où j'en suis, je me sens déconcerté(e) dérouté(e)…………………………………………….	**1**	**2**	**3**	**4**
19. Je me sens solide, posé(e), pondéré(e), réfléchi(e)……...	**1**	**2**	**3**	**4**
20. Je me sens de bonne humeur, aimable…………………..	**1**	**2**	**3**	**4**

Continuez à répondre aux questionnaires suivants, s'il vous plaît.

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Répondez à chaque question avec V (vraie) ou F (Faux)

1. J'ai de la confiance quand je dois diriger les activités des autres. _____
2. Je serais un mauvais responsable militaire. _____
3. J'aimerais bien être juge. _____
4. J'évite des postes avec le pouvoir de commander des autres personnes. _____
5. J'essaye gouverner des autres gens, plutôt de me laisser gouverner/commander. _____
6. Je n'aime pas avoir la responsabilité de diriger le travail des autres gens. _____
7. J'aimerais bien participer à la création des lois. _____
8. Être un leader ne m'intéresse pas beaucoup. _____
9. Je sais normalement gagner un débat. _____
10. Je ne me sens pas à l'aise quand je dois dire aux gens ce qu'ils doivent faire. _____
11. Il est très important pour moi d'avoir la capacité d'être un leader/directeur. _____
12. La plupart des dirigeants communautaires réussissent dans leurs activités professionnelles mieux que je ne pourrais jamais faire. _____
13. Je suis assez efficace quand il s'agit de convaincre des gens. _____
14. Pendant un débat, je n'insiste pas. _____
15. J'aimerais bien être un directeur avec le pouvoir de commander des gens. _____
16. Je ne veux pas être chargé de faire respecter la loi. _____

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Pour chacune des questions ci-dessous, veuillez utiliser cette échelle:

1	2	3	4	5	6	7
Fortement en désaccord	**En désaccord**	**Plutôt en désaccord**	**Ni en accord ni en désaccord**	**Plutôt en accord**	**En accord**	**Fortement en accord**

En ce qui concerne ma relation avec les autres

____ J'arrive à me faire écouter.

____ Mes désirs ne sont pas respectés.

____ J'arrive à influencer les gens pour qu'ils fassent ce que je veux.

____ Même si je les exprime, mes opinions n'ont pas beaucoup de portée.

____ Je pense que j'ai pas mal de poids/autorité.

____ Mes idées et opinions sont souvent ignorées

____ Même si j'essaie, je n'obtiens pas ce que je veux

____ Si j'en ai envie, on me laisse prendre les décisions

1 Sur une échelle de 0 à 5 quel est votre niveau d'anxiété à ce moment précis?

0	**1**	**2**	**3**	**4**	**5**
PAS DU TOUT ANXIEUX/STRESSE(E)					TRES ANXIEUX/STRESSE(E)

2 Sur une échelle de 0 à 5 quel est votre niveau d'anxiété à ce moment précis?

0	**1**	**2**	**3**	**4**	**5**
PAS DU TOUT ANXIEUX/STRESSE(E)					TRES ANXIEUX/STRESSE(E)

3 Sur une échelle de 0 à 5 quel est votre niveau d'anxiété à ce moment précis?

0	**1**	**2**	**3**	**4**	**5**
PAS DU TOUT ANXIEUX/STRESSE(E)					TRES ANXIEUX/STRESSE(E)

Appendix C. Experimental Protocol

Route Learning Experiment
Protocol

Rebecca Francelet
2.10.2013

Experiment Protocol - Route Learning Task

A. Set-up

1. Arrive 10 to 15 minutes before the session in the room (AAB132). Make sure the required material is in place. The material is:

- Patient sheet
  - information
  - Consent form
  - 2x STAI-S
  - PRF-d
  - General sense of power questionnaire
  - Study demographics
  - Stress level scales
- Three oral swabs
- Water and cups
- Money and payment sheet

2. Put on all four computers.
Log in: **.\LgcLab**
Password: ************

3. Run EPrime file, input subject number etc.

Participant number: begin: 1

4. Place patient sheets on tables.

B. Consent Form and Introduction (5 min)

1.

Bonjour, d'abord je vais vous donner un peu à boire pour rincer. C'est pour les échantillons de salive qu'on prendra plus tard. Merci de lire les informations et de signer le formulaire de consentement. N'hésitez surtout pas à me demander avant de signer si vous avez des questions.
Vous pouvez ensuite commencer avec le premier questionnaire, mais arrêtez-vous après, svp.

C. Saliva sample.

Voici une salivette, que l'on va utiliser pour prendre des échantillons de salive. Essayez de ne pas toucher le coton blanc avec les doigts. Mettez-le carrément dans la bouche, sous la langue. Je vais vous dire quand c'est le temps de l'enlever. Si la salivette a l'air sec, essayez de le tremper, bougez le dans la bouche.

A chaque fois que nous prenons un échantillon de salive, on va aussi vous demander de répondre à une des questions sur la dernière page de votre livret. Merci de le faire maintenant. Seulement la première question !! Puis attendez mes instructions.

Wait 1-1.5 minutes

Est-ce que la salivette est bien trempée ? OK.. Vous pouvez la remettre la salivette dans le tube, toujours sans la toucher avec les doigts.

Sip of water.

D. Route Learning Task (1) (15 min)

1. Route Learning exercise

Maintenant, on va commencer avec la première tâche sur l'ordinateur. Toutes les instructions sont données sur l'écran. Quand vous finissez, attendez mes instructions svp.

E. 2nd Saliva Sample + read instructions + answer rating scale.

F. Route Learning Task (2) (15 min)

1. Sip of water

2. Route Learning task

COMP: ***Maintenant, nous allons passer à la deuxième partie du test. Comme marqué dans les instructions, vous allez jouer les uns contre les autres, et votre performance va influencer vos gains -- de 0 à 80 francs.***

N-COMP: ***Maintenant, nous allons passer à la deuxième partie du test. La tâche est la même qu'avant.***

Silently prepare for the next part (Part 3). When ready..

Vous allez maintenant refaire la même tâche, mais cette-fois ci les routes seront montrées plus rapidement.

G. Finish questionnaire booklets.

Merci, maintenant vous pouvez finir les questionnaires, s'il vous plaît. Continuez jusqu'au bout.

H. Debrief and payment

Select winner and perform jet de dé.

Take final salivette 30 minutes post onset of Part 2.

Appendix D. Mixed Design ANOVAs

Repeated Measure ANOVA: The effect of Spatial Ability on a Route Learning Task

	General Analysis				Competition Interaction			
Variables	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Accuracy								
Spatial Ability	8.572	1, 96	.004	.082	8.367	1, 94	.005	.082
Map type	5.487	1, 96	.021	.054	5.920	1, 94	.017	.059
Competition					0.002	1, 94	.963	.000
MT*SA	0.141	1, 96	.708	.001	0.009	1, 94	.925	.000
MT*C					0.214	1, 94	.644	.002
SA*C					0.926	1, 94	.338	.010
MT*SA*C					1.921	1, 94	.169	.020
Response Time								
Spatial Ability	1.392	1, 96	.241	.014	3.991	1, 94	.049	.041
Map type	1.841	1, 96	.178	.019	0.743	1, 94	.391	.008
Competition					0.769	1, 94	.383	.008
MT*SA	7.87	1, 96	.006	.076	3.708	1, 94	.057	.038
MT*C					0.173	1, 94	.678	.002
SA*C					0.457	1, 94	.501	.005
MT*SA*C					1.152	1, 94	.286	.012
Confidence								
Spatial Ability	6.719	1. 96	.011	.065	5.772	1, 94	.018	.058
Map type	14.636	1, 96	<.001	.132	3.704	1, 94	.057	.038
Competition					3.200	1, 94	.077	.033
MT*SA	0.005	1, 96	.945	.000	0.333	1, 94	.565	.004
MT*C					0.153	1, 94	.697	.002
SA*C					0.116	1, 94	.735	.001
MT*SA*C					0.427	1, 94	.515	.005

Note. * represent interactions. MT = Map Type; SA = Spatial Ability; C = Competition; Significant at p <0.05. Significant at $p < 0.10$.

Repeated Measure ANOVA: The effect of Spatial Ability on a Route Learning Task

	General Analysis				Competition Interaction			
Variables	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Accuracy								
Trait Anxiety	5.752	1, 50	.020	.103	5.083	1, 48	.029	.096
Map type	3.824	1, 50	.056	.071	2.145	1, 48	.150	.043
Competition					3.134	1, 48	.083	.061
MT*TA	1.750	1, 50	.192	.034	0.572	1, 48	.453	.012
MT*C					0.949	1, 48	.335	.019
TA*C					0.053	1, 48	.818	.001
MT*TA*C					0.073	1, 48	.788	.002
Response Time								
Trait Anxiety	0.497	1, 50	.484	.010	.0466	1, 48	.498	.010
Map type	1.965	1, 50	.167	.038	1.888	1, 48	.176	.038
Competition					0.051	1, 48	.822	.001
MT*TA	0.162	1, 50	.689	.003	0.484	1, 48	.490	.010
MT*C					1.160	1, 48	.287	.024
TA*C					0.731	1, 48	.397	.015
MT*TA*C					4.395	1, 48	.041	.084
Confidence								
Trait Anxiety	4.028	1, 50	.050	.075	2.107	1, 48	.153	.042
Map type	8.834	1, 50	.005	.150	2.772	1, 48	.102	.055
Competition					4.920	1, 48	.031	.093
MT*TA	2.900	1, 50	.095	.055	1.983	1, 48	.166	.040
MT*C					0.045	1, 48	.833	.001
TA*C					0.000	1, 48	.991	.000
MT*TA*C					0.045	1, 48	.833	.001

Note. * represent interactions. MT = Map Type; TA =Trait Anxiety; C = Competition. Significant at p <0.05; Significant at p <0.10.

Repeated Measure ANOVA: The effect of Spatial Ability and Trait Anxiety on a Route Learning Task with Road Maps

	General Analysis				Competition Interaction			
Variables	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Accuracy								
Spatial Ability	8.133	1, 46	.006	.150	1.195	1, 42	.281	.028
Trait Anxiety	7.279	1, 46	.010	.137	3.081	1, 42	.087	.068
Competition					2.355	1, 42	.132	.053
SA*TA	1.245	1, 46	.270	.026	1.977	1, 42	.167	.045
SA*C					0.235	1, 42	.631	.006
TA*C					0.246	1, 42	.623	.006
SA*TA*C					0.090	1, 42	.766	.002
Response Time								
Spatial Ability	0.605	1, 46	.441	.013	0.258	1, 42	.614	.006
Trait Anxiety	0.432	1, 46	.514	.009	0.040	1, 42	.842	.001
Competition		1, 46			0.001	1, 42	.975	.000
SA*TA	0.056	1, 46	.814	.001	0.015	1, 42	.903	.000
SA*C		1, 46			0.306	1, 42	.583	.007
TA*C					0.627	1, 42	.433	.015
SA*TA*C		1, 46			0.272	1, 42	.605	.006
Confidence								
Spatial Ability	0.854	1, 46	.360	.018	0.430	1, 42	.516	.010
Trait Anxiety	5.083	1, 46	.029	.100	0.216	1, 42	.645	.005
Competition		1, 46			5.144	1, 42	.029	.109
SA*TA	0.014	1, 46	.906	.000	0.742	1, 42	.394	.017
SA*C		1, 46			0.090	1, 42	.766	.002
TA*C					0.425	1, 42	.518	.010
SA*TA*C		1, 46			3.685	1, 42	.062	.081

Note. * represent interactions. SA = Spatial Ability; TA =Trait Anxiety; C = Competition; significant at p <0.05; significant at p <0.10.

Repeated Measure ANOVA: The effect of Spatial Ability and Trait Anxiety on a Route Learning Task with Satellite Maps

	General Analysis				Competition Interaction			
Variables	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Accuracy								
Spatial Ability	11.185	1, 46	.002	.196	6.483	1, 42	.015	.134
Trait Anxiety	0.657	1, 46	.110	.055	2.669	1, 42	.110	.060
Competition					0.284	1, 42	.597	.007
SA*TA	0.001	1, 46	.982	.000	0.605	1, 42	.441	.014
SA*C					0.381	1, 42	.540	.009
TA*C					0.668	1, 42	.418	.016
SA*TA*C					0.087	1, 42	.769	.002
Response Time								
Spatial Ability	0.008	1, 46	.928	.000	0.299	1, 42	.588	.007
Trait Anxiety	0.236	1, 46	.629	.005	0.319	1, 42	.575	.008
Competition					0.048	1, 42	.828	.001
SA*TA	0.163	1, 46	.689	.004	0.011	1, 42	.916	.000
SA*C					0.184	1, 42	.670	.004
TA*C					0.029	1, 42	.865	.001
SA*TA*C					0.000	1, 42	.994	.000
Confidence								
Spatial Ability	0.440	1, 46	.511	.009	0.525	1, 42	.473	.012
Trait Anxiety	2.584	1, 46	.115	.053	0.021	1, 42	.885	.001
Competition					5.671	1, 42	.022	.119
SA*TA	0.028	1, 46	.867	.001	0.479	1, 42	.493	.011
SA*C					0.026	1, 42	.872	.001
TA*C					0.265	1, 42	.609	.006
SA*TA*C					2.528	1, 42	.119	.057

Note. * represent interactions. SA = Spatial Ability; TA =Trait Anxiety; C = Competition; significant at p <0.05; significant at p <0.10.