

Categorical & coordinate spatial information: Can they be disentangled in sketch maps?

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## **Categorical & coordinate spatial information: Can they be disentangled in sketch maps?**

### **Abstract**

Spatial knowledge requires the acquisition of information regarding both metric and nonmetric spatial properties of the environment. Humans encode the environment using categorical and coordinate spatial relations. The present research contributes to methods for disentangling the contribution of categories and coordinates in sketch maps and investigates the role of familiarity with spatial information in accurate encoding of these spatial relations. The results of three experiments show that as familiarity with spatial layout increases, differences between categorical and coordinate spatial relations tend to decrease. Moreover, they reveal that the way in which spatial information has been acquired – through navigation or map study - affects performance. Navigation favours coordinate encoding, while map study favours categorical encoding. In conclusion, it seems possible to extract reliable and independent information on both categorical and coordinate spatial mental representations using sketch maps.

### **Keywords**

Categorical Spatial Relations, Coordinate Spatial Relations Sketch Map, Familiarity

## 1. Introduction

Most actions that humans perform depend on their sense of space. The human sense of space in turn is formed by acting and interacting with the outside world. This interconnection allows humans to acquire, to organize and to use spatial knowledge. Spatial knowledge acquisition is an important human skill that includes the ability to encode, store and retrieve spatial information (Aguirre & D'Esposito, 1999). In this way, humans form flexible internal spatial mental representations, like cognitive maps, containing information about relationships, such as distances, positions and directions between landmarks (Tolman, 1948; O'Keefe & Nadel, 1978; Wolbers & Hegarty, 2010). The information contained in these representations includes both the metric and nonmetric spatial properties of environments (Goldin & Thorndyke, 1982; Thorndyke & Hayes-Roth, 1982). Globally, spatial properties include location, size, distance, direction, separation and connection, shape, pattern, and movements. Humans use these properties to measure and describe space in order to build mental spatial representations of the environment (Postma & Koenderink, 2016).

We can distinguish two main ways in which we build spatial representations. First, environments can be learned by people moving through those environments and directly sensing spatial features while they are driven by goal-directed exploratory behaviours (Noordzij, van der Lubbe, & Postma, 2005). In addition, humans can acquire information via symbolic sources, such as maps or language (Montello & Friendschuh, 1995). It is known that spatial information acquired through repeated exposures to the environment allows for consolidation of spatial memory traces (Burgess, 2008). In this way, people improve their spatial mental representations making them more factually correct. This internal mental representation can then be translated into external representations such as maps. Thus, it can be claimed that when people's level of familiarity with spatial information improves, they produce more precise representations of the environment.

Spatial relations form the building blocks of environmental representations. Two main classes of references can be distinguished: categorical and coordinate (Kosslyn, 1987). Categorical spatial relations refer to the relative positions of objects in space, using general spatial labels such as right and left, or above and below. Humans use categorical spatial relations in order to describe spatial situations and memorize the locations of objects. Coordinate spatial relations refer to the metric properties of objects, namely the metric distances between them: an object might be placed three centimetres from one object and farther away from another object. Humans use coordinate spatial relations in order to perform motor actions and estimate distances (e.g., Hellige & Michimata, 1989; Bullens et al., 2010, De Goede & Postma, 2015). At a neural level, categorical and coordinate spatial relations are thought to involve, as claimed by Kosslyn (1987), different hemispheric lateralization: categorical relations show a left hemispheric advantage, while coordinate spatial relations depend on

the right hemisphere.

Until now the categorical and coordinate paradigm has been applied using very simple tasks such as the Hellige and Michimata standard dot bar task (1989), and arrangements of objects or identity tasks (e.g. Ruggiero, Frassinetti, Iavarone, & Iachini, 2014; Laeng, 1994; van Asselen, Kessels, Kappelle, & Postma, 2008; Kessels, Postma, & de Haan, 1999). The results have shown that categorical judgments are easier than coordinate judgments (Bruyer, Scailquin, & Coibion, 1997; Troiano et al., 2002; Klencklen, Després, & Dufour, 2012), especially when they are combined within an allocentric reference frame (Jager & Postma, 2003; Ruotolo, van der Ham, Iachini, & Postma, 2011). In the present study, we used the categorical / coordinate distinction in a new field involving sketch maps. Sketch maps have been used to investigate geographical and spatial knowledge, by requiring participants to make drawings based on mental representations of a spatial configuration they have explored (Golledge, 2002, Blades, 1990; Saarinen & Levi, 1999). They can be considered an important tool for evaluating the spatial knowledge a person possesses (Wise & Kon, 1990). As reported by Schwering and colleagues (2014), sketch maps have been used to investigate how humans memorize spatial information. Sketch maps can be considered a reliable method to externalize internal (mental) images of the environment (Bosco, Lopez, Caffò, Postma, submitted; Blades, 1990). Therefore, we can consider sketch maps as external representations of cognitive maps, specifying how the sketchers remember the spatial world. In a previous study (Bosco et al., submitted), we showed for the first time that it is possible to separately evaluate categorical and coordinate estimates of spatial relations using a very simple form of sketch map based on a goal directed exploration of a university campus.

The aim of the present research was to investigate the possibility of studying categories and coordinate relations in sketch maps, extending the work by Bosco and colleagues (submitted) by taking into account different factors that affect the encoding of spatial relations. In order to achieve this purpose, we implemented three studies, as follows.

*Experiment 1* aimed to evaluate categorical and coordinate spatial relations (an integrated outcome of spatial information regarding distances and positions), with particular attention to mental spatial representations derived from geographical areas acquired not only through direct navigation, but also from the study of maps. Familiarity with a physical environment allows people to solve location tasks (De Goede & Postma, 2015). Experiencing distances in a perceptual and goal directive way through navigation (the Map of the Campus) could enhance encoding coordinate components compared with a map study learning format (the Map of Apulia and the Map of Italy).

*Experiment 2* examined mental representations based only on study of maps and considered how levels of familiarity with the environment affected encoding accuracy. A number of research

projects have investigated the relationship between an individual's accuracy on cognitive map tasks and their level of familiarity with to-be-recalled layouts (e.g., Lloyd & Patton, 2011). Frequent experience with spatial targets allows people to precisely know where a target landmark is located in map-like tasks, and in perceptual and visual search tasks, and to solve difficult distance knowledge problems (e.g., Desimone & Duncan, 1995). As already shown by Lopez and colleagues (2018a, 2018b, 2019), people can easily solve position tasks based on well consolidated information. In particular, familiarity allows learning more precise coordinate information for city locations (Lloyd & Patton, 2011). In light of the foregoing, the aim of *Experiment 2* was to assess the effect of familiarity with three maps ordered with respect to familiarity (the Map of the Italy, the Map Northern Europe and the Map of the World). The higher the level of familiarity, the smaller the difference in accuracy between categories and coordinate information should be.

*Experiment 3* was also devoted to investigating the role of familiarity with maps. We wanted to explore how spatial relations were encoded by two groups of young participants coming from different countries. For this purpose, we decided to manipulate their familiarity with spatial information in a different way from that used in the previous experiments, that is, by exploiting the fact that people have better knowledge of their home country than other countries. Moreover, we wanted to ascertain if it is correct to continue supporting, in agreement with previous research, the notion that categorical judgments are easier than coordinate judgements, even for tasks based mainly on map study (e.g., Bruyer et al., 1997). To determine the contribution of relatively independent categorical and coordinate components to sketch maps according to the (quasi-experimental, ecological) manipulation of the level of familiarity with spatial information, we investigated what happened when the level of familiarity with maps was presumably high or low. Testing samples of Italian and Dutch students, we first measured "Accuracy across Countries", in which distances and the relative distances of triplets of cities were evaluated for the Map of The Netherlands and the Map of Italy. Second, we measured "Accuracy across European Regions" by testing spatial encoding for the Maps of Northern Europe and Southern Europe. Dutch students were expected to exhibit less difference between categories and coordinates for the Maps of the Netherlands and Northern Europe, compared to the Maps of Italy and Southern Europe. Conversely, an inversion of this pattern of results was expected for the Italian sample. Further, for all students, a greater difference would be expected in the comparison of Accuracy across countries than the comparison of Accuracy across European Regions.

Finally, we highlighted the role of familiarity in the categorical and coordinate distinction by also including gender differences. The role of gender has been extensively investigated in spatial cognition. Generally, it has been reported that males outperform female participants in tasks based

on coordinate evaluation, while females are better able to perform categorical tasks (e.g. Postma, Izendoorn, & De Haan, 1998; Voyer, Postma, Brake, & Imperato-McGinley, 2007), but this evidence cannot be considered consistent (van der Ham & Borst, 2011). Moreover, as stated by Palermo and colleagues (2012) these differences might be attributable to different levels of familiarity with landmarks.

## 2. General Method

### *2.1 Characteristics of the task*

In the present research, a series of geographic areas were used as stimuli. The extent of these areas ranged from approximately 6.6 square kilometres (Map of the Campus) to 16M square kilometres (Map of the World). Moreover, in order to compare these very different geographical stimuli, we used a “sketching area”, namely an empty box (see Figure 1) measuring 11.3x12 cm (e.g., De Goede & Postma, 2015), given to participants, in which they were to mark the landmarks for each area. Keeping in mind metric (i.e., relative distances) as well as categorical (“A is above/below and left/right of B”) spatial relations between landmarks (see Figure 5), participants responded to the following instructions: “Think of the spatial relationships between the landmarks. In the box below, draw three crosses, corresponding to the landmarks, and label them. Please, use the full box. Please, be careful to respect the proportional distances between landmarks and their correct positions”. Consequently, although the scale of the maps varied greatly, participants were nonetheless forced to use the same box to represent different geographical areas.

*Insert Figure 1 here*

The tasks were based on pinpointing only three highly memorable landmarks (architectural elements for the Map of Campus, and cities for the other Maps, see below). The selection of the landmarks in each geographical area was based on a pilot rating students’ level of knowledge and familiarity with landmarks. The final choice was the result of a compromise between the need to take into account landmark memorability, and the discriminability of a landmark’s position and distance from other landmarks. The tasks administered are presented below.

The *Map of Campus* (see Figure 2, Experiment 1) included three very familiar landmarks: the entrance to the Student Center, the entrance of the Department and the stairs of the Salone degli Affreschi inside the main building of the University. The walkable area of the campus was

approximately 6.6 km<sup>2</sup> (see distances in Table 1). The stated scale (relationship between distances on a map and distances in real life) was 1cm = 19 m. The way in which participants had learnt the entire area was mainly through repeated navigation experiences.

*Insert Table 1 and Figure 2 here*

The *Map of Apulia* (see Figure 3, Experiment 1) included three landmarks: Bari, Brindisi and Taranto. The area investigated was approximately 2450 km<sup>2</sup> (see distances in Table 2). The stated scale was 1cm = 14.5 km. The way in which participants had learnt the entire area was most likely mixed, through both navigation and map study experiences.

*Insert Table 2 and Figure 3 here*

The *Map of Italy* (see Figure 4, all experiments) included three landmarks: Genoa, Naples and Cagliari. The area of the region investigated was approximately 128600 km<sup>2</sup> (see distances in table 3). The stated scale was 1cm = 110 km. The way in which participants had learnt the entire area was mainly through map study.

*Insert Table 3 and Figure 4 here*

The *Map of The Netherlands* (see Figure 5, Experiment 3) included three landmarks: Groningen, Maastricht and Den Haag. The area of the country investigated was approximately 16700 km<sup>2</sup> (see distances in Table 4). The stated scale was 1cm = 18 km. The way in which participants had learnt the entire area was mainly through map study. The present map was employed in Experiment 3.

*Insert Table 4 and Figure 5 here*

The *Map of Northern Europe* (see Figure 6, Experiments 2 and 3) included three landmarks: Paris, London and Amsterdam. The area of the country investigated was approximately 63012 km<sup>2</sup> (see distances in Table 5). The stated scale was 1cm = 162 km. The way in which participants had learnt the entire area was mainly through map study.

*Insert Table 5 and Figure 6 here*

The *Map of Southern Europe* (see Figure 7, Experiment 3) was composed of three landmarks: Rome, Lyon and Palma de Mallorca. The area of the country investigated was approximately 255000 km<sup>2</sup> (see distances in table 6). The stated scale was 1cm = 228 km. The way in which participants had learnt the entire area was mainly through map study.

*Insert Table 6 and Figure 7 here*

The *Map of the World* (see Figure 8, Experiment 2) included three landmarks: New York, Rio de Janeiro and Cape Town. The area of the area investigated was approximately 16M km<sup>2</sup> (see distances in Table 7). The stated scale was 1cm = 1166 km. The way in which participants had learnt the entire area was mainly through map study.

*Insert Table 7 and Figure 8 here*

Considerable effort was made to ensure the difficulty of these different tasks was approximately the same. Task difficulty was evaluated from both the categorical and coordinate points of view.

Starting from the actual position of the landmarks on the scaled map (we scaled each spatial configuration to 11.3x12 cm, the size of the empty box), we noted their position (see Figure 9) with respect to the North/South and East/West axes: a) if the actual  $\Delta \lambda$  or  $\Delta \Phi$  was respectively less than or equal to 1.5 cm (taking into account the sketching area), the categorical judgment was considered to be of high difficulty, and 3 points were assigned; b) if the  $\Delta \lambda$  or  $\Delta \Phi$  were respectively more than 1.5 cm and less or equal to 3 cm, the categorical judgment was considered to be of medium difficulty, and 2 points were assigned; and c) if the  $\Delta \lambda$  or  $\Delta \Phi$  were respectively more than 3 cm, the categorical judgment was considered to be of low difficulty, and 1 point was assigned. The lower the sum on each axis, the lower the level of task difficulty (maximum score 18).

*Insert Figure 9 here*

Task difficulty was also measured as the difference of distances between landmarks (A to B vs A to C) on the scaled map: a) If the difference of distances was less than or equal to 1.5 cm, the coordinate judgment was considered to be of high difficulty, and 3 points were assigned; b) if the difference of distances was more than 1.5 cm or less than or equal to 3 cm, the coordinate judgment was considered to be of medium difficulty, and 2 points were assigned, and c) if the difference of distances was more than 3 cm, the coordinate judgment was considered to be of low difficulty, and 1 point was assigned. The smaller the sum on each axis, the lower the level of task difficulty (maximum score 18). Tables 8 and 9 report the level of categorical and coordinate difficulty for each task for the x and y axes, respectively. From the categorical point of view, the Map of Southern Europe seemed to be more difficult than the others. In particular, the categorical judgements that seemed to present most difficulty were: on the x axis, the comparison between Lyon and Palma de Mallorca, and on the y axis, the comparison between Lyon and Rome. As for coordinates, it seemed to be very hard to make judgements regarding the distances between

landmarks on the Maps of Northern and Southern Europe. In the case of Northern Europe all the comparisons were very tough.

*Insert Tables 8 and 9 here*

#### *Scoring method*

In order to assess category judgements, participants were asked to consider three landmarks pinpointed in the empty box (see Figure 10) and to make categorical judgements for each pair of landmarks, separately specifying relations for the x (B is on the right of C) and y axes (B is above C). For each correct categorical spatial relationship, they were awarded from 1 to a maximum of 6 points (three levels for each axis).

*Insert Figure 10 here*

In order to assess coordinate judgements, participants were asked to consider the same three landmarks pinpointed in the empty box (see Figure 11). Coordinate judgments were made for each pair of landmarks by comparing distances, separately, on the x (the distance between landmarks B and C is greater than the distance between the landmarks A and C) and y axes (the distance between landmarks B and C is less than the distance between landmarks A and C). For each correct coordinate spatial relation, it was possible to assign 1 point to a maximum of 6 points (three comparisons for each axis).

*Insert Figure 11 here*

### **3. Experiment 1**

Experiment 1 aimed to assess the effect of repeated exposures to the environment (goal-directed behaviours of exploration vs map study) on the accuracy of categorical and coordinate encoding, using position tasks related to the Map of the University Campus, the Map of Apulia and the Map of Italy.

#### 3.1 Method

##### *3.1.1 Participants*

One hundred and sixty-eight healthy participants, 86 females, between 19 and 30 years of age (age mean±sd: 21.75 ± 2.41) took part in the study. All participants were Italian university

students from introductory courses in psychology at the University of Bari. The level of education for the overall sample was 15.22 (sd=1.3). The whole sample was admitted to the assessment aimed which evaluated their ability to retrieve allocentric spatial information previously learned mainly through navigation, and map study.

All participants, blinded to the hypothesis of the study, signed a consent form and were unaware of the aims of the study. The participants were enrolled between November and December 2017. The Local Ethical Committees of the Institutions approved the study protocol.

### *3.1.2 Materials and procedure*

Three categorical/coordinate position tasks were administered:

- a) The Map of Campus
- b) The Map of Apulia
- c) The Map of Italy

Participants were university students, who had lived in Bari from birth. All the participants had a global level of familiarity with the geographical areas investigated. For the Map of Campus, participants indicated how many times the landmarks had been visited every week on a scale from 1, never, to 7, every day. Moreover, in order to investigate their level of familiarity with the other two maps participants were rated on four items: the use of Google Maps, Paper Maps, Weather Forecast and the Study of Geography, on a scale from 1 (= never) to 7 (= always) (see Table 10).

The entire procedure was made clear to the participants beforehand. Participants were assessed individually in a well-lit and quiet room without disturbances. Data were collected in one session. The whole assessment lasted a maximum of 20 minutes.

## 3.2 Results

Descriptive statistics and preliminary analysis of the inclusion criteria were performed, as reported in Table 10.

In order to accomplish the purpose of the present experiment, a mixed factor Anova was performed, with Gender as between-subject variables, Map (three levels: the Map of Campus, the Map of Apulia, and the Map of Italy) and Spatial relation (two levels: category and coordinate) as repeated measure variables.

The results were as follows: the main effect of Map ( $F(2, 166) = 18.01, p < 0.001; \eta_p^2 = 0.09$ ) proved to be significant (Means and sds: the Map of Campus  $4.91 \pm 0.06$ ; the Map of Apulia  $4.45 \pm 0.05$ , and the Map of Italy  $4.35 \pm 0.08$ ). The post-hoc analysis showed a significant difference between the Map of Campus and the Maps of Apulia and Italy. No differences were found

between the latter two maps. Moreover, the Map x Gender interaction ( $F(2, 166) = 4.65, p < 0.01; \eta_p^2 = 0.03$ ) was also significant (the Map of Campus: male mean $\pm$ sd =  $4.9 \pm 0.09$ ; female mean $\pm$ sd =  $4.9 \pm 0.09$ , the Map of Apulia: male mean $\pm$ sd =  $4.4 \pm 0.07$ ; female mean $\pm$ sd =  $4.5 \pm 0.07$ ; the Map of Italy: male mean $\pm$ sd =  $4.5 \pm 0.11$ ; female mean $\pm$ sd =  $4.1 \pm 0.11$ ). From the inspection of the means an advantage for Male emerged for the Map of Italy, and a similar performance on the Map of Campus and Apulia. Finally, the interaction Map x Spatial relation ( $F(2, 166) = 4.75, p < 0.001; \eta_p^2 = 0.03$ ) was also significant. Inspection of the graph (see Figure 12) revealed an advantage for Coordinate over Category of 0.18 for the Map of the Campus, a substantial draw between the two components for the Map of Apulia, and an advantage of 0.18 for Category over Coordinate for the Map of Italy. No other main effects or interaction effects were significant.

*Insert Table 10 and Figure 12 here*

### 3.4 Discussion

This study compared the performance of a group of young participants on three different position tasks based on information acquired through the study of maps, repeated episodes of navigation and mixed strategies. Using the Map of the Campus, the Map of Apulia and the Map of Italy, we examined encoding of categorical and coordinate spatial relations, applying this paradigm to sketch maps. All the participants were enrolled in the study on the basis of their self-reported level of familiarity with maps and school experience with scientific matters. As shown in Table 8 there were no differences between males and females in terms of geographic skills. However, male participants claimed more familiarity with the Map of Campus and the Map of Italy in terms of self-reported global spatial experience.

Participants performed better on the Map of Campus than the other two maps, showing the positive effect of repeated experiences of navigation on the maintenance of the memory trace. However, as shown in Tables 8 and 9, there was a slight advantage for the Map of Campus compared to the Map of Apulia and the Map of Italy in terms of coordinate judgements (the scores differ by three and one points, respectively).

Moreover, participants' performance also showed a coordinate advantage for the Map of Campus. By contrast, they showed a categorical advantage in the task based on information acquired primarily through map study (the Map of Italy). Furthermore, participants showed a balance between the categorical and coordinate components of spatial relations in the task characterized by a mixed format of learning (Map of Apulia). Structurally, the Map of Apulia seemed to be more difficult than

the other maps from the coordinate point of view (see General Methods), but the results support the hypothesis that exploration of the environment improves people's ability to solve distance judgements.

Finally, regarding gender effects, males seemed to outperform female participants in the Map of Italy based on allocentric information. This result was in line with other research that supports gender differences, with males performing better in spatial tasks (for a review, de Goede, 2009). In addition, male participants seemed to overestimate their spatial competence in the self-report questionnaire used to collect information (Brackett & Rivers, 2006; Cornell, Sorenson, & Teresa Mio, 2003), but this evidence did not have an effect on their performance. It is plausible to assume that higher familiarity with landmarks contributed to reducing gender differences.

A potential weakness of this experiment was the presence of two distinct sources of variation: the format of learning (map study, navigation, mixed) and the level of familiarity. Therefore, Experiment 2 was devoted to deepening our understanding of the role of familiarity by comparing only spatial information acquired through map study.

## **4. Experiment 2**

The aim of Experiment 2 was to verify the effect of familiarity on the accuracy of spatial encoding using tasks based on spatial information primarily acquired through map study. We predicted that greater familiarity would result in a smaller difference in the contribution of categories and coordinates.

### 4.1 Method

#### *4.1.1 Participants*

One hundred and twenty healthy participants, 60 females, between 19 and 30 years of age (age mean $\pm$ sd: 21.42  $\pm$  2.14) took part in the study. All participants were university students from introductory courses in psychology. The level of education for the overall sample was 15.15 (sd=0.9). The whole sample was admitted to the assessment, which aimed at evaluating their ability to retrieve allocentric spatial information previously learned mainly as an effect of map study. The enrolment procedure was the same as that for *Experiment 1*.

#### *4.1.2 Materials and procedure*

Three categorical/coordinate position tasks were administered:

- a) The Map of Italy
- b) The Map of Northern Europe
- c) The Map of the World

The setting, procedures and inclusion criteria were the same as in *Experiment 1*.

## 4.2 Results

Descriptive statistics and preliminary analysis of the inclusion criteria was performed, as reported in Table 11.

In order to achieve the aim of this experiment, a mixed factor Anova was performed, with Gender as between-subject variables, Map (three levels: the Map of Italy, the Map of Northern Europe, and the Map of the World) and Spatial relation (two levels: category and coordinate) as repeated measure variables.

The results were as follows: the main effect of Map ( $F(2, 117) = 9.96, p < 0.001; \eta_p^2 = 0.07$ ) proved to be significant (Means and sds: the Map of Italy  $4.29 \pm 0.10$ ; the Map of Northern Europe  $3.72 \pm 0.07$ , and the Map of Italy  $4.14 \pm 0.11$ ). The post-hoc analysis showed a significant difference between the Map of Northern Europe and the Maps of Italy and the World. In addition, a main effect of Spatial relation ( $F(1, 117) = 143.57, p < 0.001; \eta_p^2 = 0.55$ ) was found (Means and sds: category  $4.37 \pm 0.06$ ; coordinate  $3.73 \pm 0.06$ ). Moreover, the Map x Gender interaction ( $F(1, 117) = 5.21, p < 0.001; \eta_p^2 = 0.04$ ) was also significant (the Map of Italy: male mean $\pm$ sd =  $4.55 \pm 0.14$ ; female mean $\pm$ sd =  $4.03 \pm 0.14$ , the Map of Northern Europe: male mean $\pm$ sd =  $3.61 \pm 0.10$ ; female mean $\pm$ sd =  $3.82 \pm 0.11$ ; the Map of the World: male mean $\pm$ sd =  $3.98 \pm 0.16$ ; female mean $\pm$ sd =  $4.30 \pm 0.16$ ). Finally, Map x Spatial relation ( $F(2, 117) = 36.02, p < 0.001; \eta_p^2 = 0.23$ ) was also significant. From inspection of the graph (see Figure 13), a general advantage emerged for category over coordinate: for the Map of the Italy this advantage amounted to 0.22, for the Map of Northern Europe there was an advantage of 1.3 and for the Map of the World an advantage of 0.43. No other main or interaction effects were significant.

## 4.3 Discussion

Experiment 2 compared the performance of a group of university students on three different position tasks based on information acquired mainly through map study: the Map of Italy, the Map of Northern Europe and the Map of the World. In this study, another fundamental variable played an important role: familiarity with the maps. Putting aside the format of learning, we equated familiarity with geographical knowledge. All the participants were enrolled in the study on the basis of their self-

reported level of familiarity with maps and school experience with scientific matters. There were no differences between males and females in geographic skills. However, male participants declared more familiarity with the Map of the Northern Europe. No one was excluded from the sample.

Again, the major pattern of results was in line with expectations. Globally, the level of self-reported familiarity with the Map of Italy was higher than that for the Maps of Northern Europe and the World. The better performance of participants on the Map of the World compared to the Map of Northern Europe was probably due to structural effects in the latter map. Notwithstanding the memorability of the cities, the Map of Northern Europe seemed to be more difficult. As can be seen in Tables 8 and 9, the overall advantage shown for the Map of the World is most likely a consequence of the relative ease of making comparisons between cities on the Map of the World compared to the Map of Northern Europe.

Moreover, in our view it should be noted how geographers represent space in two-dimensional images. It is worth noting that the creation of a map entails a key problem: how to turn the three-dimensional sphere of the Earth into a flat surface. Generally, a planisphere map results in a huge distortion of the relative sizes of the continents, dramatically shrinking Africa and making Northern Europe smaller than it actually is. Mapmakers have to choose a projection of the globe that approximates the basic properties of shape, size, direction, distance and scale. This inaccurate view of the size of the Western World results in an inaccurate and unclear spatial mental representation of Northern Europe (Snyder, 1987; Snyder & Maling, 1993). Thus, maps distort reality and convey bias: humans will acquire misleading perceptions of the distances and alignments between cities. Consequently, in the case of Northern Europe the low performance participants exhibited in judging distances can presumably be ascribed not only to limitations in map construction (e.g., choice of landmarks), but also to cognitive distortions in the mental representation of that geographical area, notwithstanding the participants' self-report regarding their good level of knowledge of this spatial configuration.

Generally speaking, the judgement of categorical spatial relations was shown to be easier in all tasks based on allocentric spatial information acquired through map study. Once again, this result is in line with previous findings (Bruyer et al., 1997; Troiano et al., 2002; Klencklen et al, 2012). But the more interesting result concerns the effect of familiarity with maps: differences between performance with categorical and coordinate spatial relations decreased as the supposed level of familiarity of the geographical area increased (Lloyd & Patton, 2011). As shown before, the difficulty of the Map of the Northern Europe was evident in coordinate performance and suffered a drastic

decrease probably linked to the complexity of distance comparisons between London, Paris and Amsterdam.

Finally, regarding gender effects, the results were not in line with expectations. Men outperformed women in the Map of Italy, as in the previous study, but female participants outperformed male participants on the Map of Northern Europe and the Map of the World. Yet, female participants had a lower level of familiarity with the Maps of Northern Europe and the World than males. Probably, given that familiarity was self-evaluated, males overestimated their level of familiarity, while, on the contrary, female participants underestimated their knowledge. This evidence has already been reported by Brackett & Rivers in 2006.

*Insert Table 11 and Figure 13 here*

## **5. Experiment 3**

The last experiment investigated another aspect of familiarity: the different origin countries of the participants. Having different degrees of knowledge might have had an effect on spatial encoding.

### 5.1 Method

#### *5.1.1 Participants*

Eighty healthy participants, 40 females, between 19 and 30 years of age took part in the study. All participants were university students coming from different faculties. The overall sample included 40 Dutch and 60 Italian participants. The mean age for the Dutch was 23.01 (sd=3.01) and for the Italians was 24.35 (sd=4.05). The level of education for the Dutch was 14.40 (sd=1.89) and for the Italians was 15.90 (sd=0.98).

All participants signed a consent form and were ignorant of the aims of the study. The participants received 5 euros (Dutch students) or 0.5 course credits for participation (Dutch and Italian). They were enrolled between February and April 2018. The local ethical committees of the Institutions approved the study protocol.

#### *5.1.2 Materials and procedures*

The inclusion criterion for young participants was to have lived in their country from birth and not to have navigational-related complaints as assessed by a wayfinding questionnaire. The

Wayfinding Questionnaire (WQ, van der Ham, Kant, Postma, & Visser-Meily, 2013) was used to screen for navigation related complaints. It is a self-report instrument of navigational ability that includes 22 items related to navigation, mental transformation, distance estimation, orientation and sense of direction. High values on the Spatial Anxiety Scale represented higher anxiety about spatial and navigational abilities, on a scale from 1 (= not at all applicable to me/ not uncomfortable at all) to 7 (= fully applicable to me/ very uncomfortable). No one was excluded from the sample. Moreover, all participants were rated on their knowledge of Maps as in the previous experiments (see Table 13). Four categorical/coordinate position tasks were administered:

- a) The Map of Italy
- b) The Map of the Netherlands
- c) The Map of Northern Europe
- d) The Map of Southern Europe

The setting and procedure of administration were the same as in the previous experiment.

## 5.2 Results

Descriptive statistics and preliminary analysis of the inclusion criteria was performed, as reported in Tables 12 and 13.

In line with the first aim of Experiment 3 (Accuracy across Countries), a mixed factor Anova was performed, with Group (two levels: the Italians, the Dutch) and Gender as between-subject variables, Map (two levels: the Map of Italy, the Map of The Netherlands) and Spatial relation (two levels: category and coordinate) as repeated measure variables. The results were as follows: the main effects of Group ( $F(1, 78) = 37.07, p < 0.001; \eta_p^2 = 0.33$ ) proved to be significant (Means and sds: the Italians  $3.57 \pm 0.09$ ; the Dutch  $4.38 \pm 0.09$ ). In addition, the main effect of Spatial relation ( $F(1, 78) = 30.29, p < 0.001; \eta_p^2 = 0.28$ ) was present (Means and sds: category  $4.19 \pm 0.07$ ; coordinate  $3.77 \pm 0.08$ ). Moreover, the Group x Map interaction ( $F(1, 78) = 98.16, p < 0.001; \eta_p^2 = 0.56$ ) was also significant (the Map of Italy: the Italians  $\text{mean} \pm \text{sd} = 4.46 \pm 0.15$ ; the Dutch  $\text{mean} \pm \text{sd} = 2.68 \pm 0.12$ , the Map of The Netherlands: the Italians  $\text{mean} \pm \text{sd} = 3.80 \pm 0.15$ ; the Dutch  $\text{mean} \pm \text{sd} = 4.97 \pm 0.12$ ). Additionally, Group x Spatial relation ( $F(1, 78) = 8.04, p < 0.01; \eta_p^2 = 0.10$ ) was also significant (the Italians: category  $\text{mean} \pm \text{sd} = 3.68 \pm 0.10$ ; coordinate  $\text{mean} \pm \text{sd} = 3.47 \pm 0.12$ ; the Dutch: category  $\text{mean} \pm \text{sd} = 4.70 \pm 0.10$ ; coordinate  $\text{mean} \pm \text{sd} = 4.07 \pm 0.12$ ). Furthermore, Map x Spatial relation ( $F(1, 78) = 19.72, p < 0.001; \eta_p^2 = 0.21$ ) was also significant (the Map of Italy: category  $\text{mean} \pm \text{sd} = 4.15 \pm 0.10$ ; coordinate  $\text{mean} \pm \text{sd} = 4.11 \pm 0.13$ ; the Map of the Netherlands: category  $\text{mean} \pm \text{sd} = 4.22 \pm 0.10$ ; coordinate

mean±sd = 3.43± 0.11). Finally, Group x Map x Spatial relation ( $F(1, 78) = 17.18, p < 0.001; \eta_p^2 = 0.18$ ) was also significant. From the inspection of the graph (see Figure 14), a general advantage for category over coordinate emerged: for the Map of the Italy, the Italians showed an advantage for categories over coordinates of 0.5, and the Dutch an advantage of 0.7; for the Map of the Netherlands the Italians showed an advantage for categories over coordinates of 0.8 and the Dutch an advantage of 0.5. Moreover, the Map of the Netherlands is comparable to the Map of Italy and the Dutch were more accurate than the Italians. No other main or interaction effects were significant.

Regarding the second aim (Accuracy across European Region), a mixed factor Anova was performed, with group (two levels: the Italians, the Dutch) and gender as between-subject variables, Map (two levels: the Map of Northern Europe, the Map of Southern Europe) and Spatial relation (two levels: category and coordinate) as repeated measure variables. The results were as follows: a main effect of spatial relation ( $F(1, 78) = 42.36, p < 0.001; \eta_p^2 = 0.36$ ) was found (Means and sds: category 5.03±0.07; coordinate 4.57±0.13). Furthermore, Map x Spatial relation ( $F(1, 78) = 17.33, p < 0.001; \eta_p^2 = 0.19$ ) was also significant (the Map of Northern Europe: category mean±sd = 4.97±0.08; coordinate mean±sd = 4.75±0.16; the Map of Southern Europe: category mean±sd = 5.11±0.10; coordinate mean±sd = 4.38±0.15). Finally, Group x Map x Spatial relation ( $F(1, 78) = 16.67, p < 0.001; \eta_p^2 = 0.18$ ) was also significant. From the inspection of the graph (see Figure 15) a general advantage for categorical over coordinate spatial relations emerged: for the Map of the Northern Europe the Italians showed an advantage for coordinates over categories of 0.2. The Dutch, by contrast, showed an advantage for categories over coordinates of 0.4. For the Map of Southern Europe, the Italians showed an advantage for categories over coordinates of 0.9 and the Dutch an advantage for categories over coordinates of 0.6. Moreover, the Map of Northern Europe was comparable to the Map of Southern Europe and the Dutch and Italians performed similarly. No other main or interaction effects were significant.

*Insert Table 12 and Table 13 here*

### 5.3 Discussion

The present study compared the performance of Italian and Dutch students, on four position tasks based on information acquired mainly through the study of maps. In order to investigate the “Accuracy across Countries” we used the Map of Italy and the Map of the Netherlands; for the “Accuracy across European Region” we used the Maps of Northern and Southern Europe.

Focusing on the way in which geographical information was acquired and the level of familiarity with maps, we investigated the difference between categories and coordinates. Moreover,

with this experiment we studied the same phenomenon from a cross-cultural perspective, observing how nationality intersected with the other variables mentioned above.

The two groups were comparable in terms of demographic variables, school subject preferences and skills, and wayfinding abilities. We also asked questions about the study of geography at school and their level of familiarity with the geographic areas investigated. As shown in Table 13 there was a significant difference between the Dutch and Italian students with respect to their level of familiarity with their own country and the foreign country. No differences between the Dutch and Italian students emerged for the Northern and Southern Europe maps. Nonetheless, the Northern map appeared to be more familiar overall to both samples than the Southern map.

In the “Accuracy across Countries” analysis, the Dutch were more accurate than the Italian students in their sketch maps. Probably Dutch students have been more exposed to maps, and in particular to the Map of Italy, and the salient shape that sets it apart in Europe, consolidating the memory trace (Thomas et al., 2016). However, opportunities for travel between the Dutch and Italian cities cannot be excluded.

Generally, both the Dutch and the Italians participants were more accurate in categories than in coordinate relations. More importantly, the difference between performance on the categorical and coordinate spatial relations decreased with familiarity. This result is in line with the findings from the previous experiments, showing again the influence of familiarity with maps on spatial encoding. The Italian students showed better competence on the Map of Italy. Across their lifetimes, they had more exposure to that map and had acquired more information regarding the configuration of Italian cities. Conversely, the Dutch were better able to pinpoint the Dutch cities. The decrease in the difference between category and coordinate accuracy as an effect of familiarity again shows the importance of investigating spatial mental mechanisms regarding information well consolidated in memory.

The “Accuracy across European Regions” showed very similar performance levels across the Dutch and the Italians. Their similar performance was justified by similar levels of knowledge about the geography of Europe. However, Northern Europe appeared to be more familiar than Southern Europe for both groups. Also, in the case of “Accuracy across European Regions” the same pattern of results, regarding the difference between categorical and coordinate spatial information, recurred: the higher the level of familiarity, the lower the difference between categorical and coordinate levels of accuracy.

No gender differences emerged. In the present experiment we added gender as a between subject factor, only to make it coherent with the previous statistical analyses.

*Insert Figure 14 and Figure 15 here*

## **6. General Discussion and Conclusion**

Spatial relations can be encoded in terms of categories and coordinates. The categorical spatial relations are abstract, and they are described with spatial labels useful for viewpoint independent object recognition and spatial location tasks (Kosslyn et al., 1987; Jager & Postma, 2003). Coordinate spatial relations, instead, refer to metric properties, and are, amongst other purposes, necessary to guide precise movements (Bullens & Postma, 2008). Coordinate judgements seem to be more difficult to make than categorical judgements (van der Ham & Borst, 2011) possible because encoding coordinates entails a perceptual effort for judging metric spatial information (e.g., Bruyer et al., 1997; Troiano et al., 2002; Klencklen et al., 2012; Kranjec, Lupyan, & Chatterjee, 2014).

This is one of the first studies looking at the application of categorical and coordinate relation measures using sketch maps of different scales and familiarity. As already suggested by Bosco and colleagues (submitted), it is formally and empirically appropriate to separate coordinate and categorical components of spatial information in sketch maps. Sketch maps are representations of the environment in which distances, directions and positions are integrated. In this research we wanted to investigate the difference between categories and coordinates in maps based on different geographical information: primarily learned from repeated episodes of exploration, from map study and from both. Moreover, we added another variable potentially affecting performance: the level of familiarity with maps.

The way in which spatial information is acquired (moving in the environment mainly through goal-directed behaviours of exploration or via symbolic sources such as map study), and the level of familiarity with spatial and geographical configurations both play an important role in spatial cognition. In Experiment 1 we focused on different kinds of learning of spatial information, applying the categorical and coordinate paradigm to the Map of the Campus, the Map of Apulia and the Map of Italy. The results showed a positive effect of having learned spatial information through navigation on the accuracy with which coordinates were encoded and retrieved. Moreover, there was a close draw between categories and coordinates in the Map of Apulia, where the kind of spatial learning was likely to be mixed. Finally, for the Map of Italy categorical proved to be more important than coordinate spatial information.

In the second experiment we employed mainly allocentric maps, taking into account participants' familiarity with the geographical areas. Using the Map of Italy, the Map of Northern Europe and the Map of the World, the difference in performance between categorical and coordinate spatial relations decreased with the increase in self-reported level of familiarity with the geographical area (Lloyd & Patton, 2011). For the first time, this result has been confirmed using sketch maps. In addition, categorical spatial relations were better determined than coordinates, showing that the former were easier when mainly allocentric spatial information (acquired mainly via map study) was involved (e.g., Klencklen et al, 2012).

Regarding gender differences, men outperformed women in the Map of Italy (Experiments 1 and 2), and this result was in line with previous findings in which women showed difficulties in the manipulation of allocentric spatial information (e.g., Picucci et al., 2010). An interesting result emerged with respect to female performance on the Map of Northern Europe and the World Map (second experiment). In both of these cases, women outperformed men. Nonetheless, they underestimated their geographic abilities as emerged from the self-report questionnaire (Brakett & Rivers, 2006; Cornell et al., 2003). However, it is possible to claim that the level of familiarity with spatial information might be crucial in observed gender differences among participants.

The data emerging from the third experiment were in line with previous findings. Introducing nationality as another variable of study, we compared Italian and Dutch students. The results suggested that categorical spatial relations were easier for both groups in all tasks. Moreover, in order to disentangle categorical and coordinate spatial relations we applied this spatial configuration paradigm to sketching maps with different levels of familiarity for the participants. Generally speaking, Dutch participants showed higher accuracy across tasks. On the basis of familiarity with the Map of Italy and the Map of the Netherlands, the Italian and the Dutch groups seemed to manipulate spatial information better for their own country. Conversely, no differences emerged between the Dutch and the Italians for more global geographical areas such as Northern and Southern Europe (both in self-reported and objective measures). Exposure to these spatial maps seemed to be more universal, perhaps due in part to the fact that the Italian and the Dutch levels of education were comparable. Most importantly, these results show that the difference between accuracy on categorical and coordinate spatial relations decreases with increasing levels of familiarity with the relevant geographical area (Lloyd & Patton, 2011).

The present research has some limitations. Notwithstanding our efforts to build ecological spatial tasks based on a standardized method (e.g. Lopez et al., 2018a, 2018b; Lopez et al., 2019), the Map of Northern Europe was very difficult for participants to complete. Unlike laboratory-

based psychometric tasks, the use of more ecological tasks means that some variables are not under the perfect control of the researcher, such as the spatial arrangements used in paper maps, which generate distortions and biases in the mental representation of space (Snyder, 1987; Snyder & Maling, 1993) and the difficulty of soliciting remotely acquired spatial knowledge.

In summary, our findings have contributed to a better understanding of categorical and coordinate processes involved in encoding spatial relations. In particular, it emerged that navigation stimulated coordinate encoding. This result could be explained by the fact that exact spatial properties are essential for navigation (such as exact distance and direction), and familiarity also enhanced coordinate processing. On the other hand, categorical spatial relations were rapidly processed, and seemed to be less influenced by the effect of familiarity.

In conclusion, internal representations of the outside world can be obtained by sketch maps at different scales. The sketch map representation contains both categorical and coordinate spatial relations. We have demonstrated the usefulness of a new methodology able to disentangle categorical and coordinate spatial relations, and we have shown how familiarity with landmarks influenced their encoding.

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**Declaration of interest:**

None.

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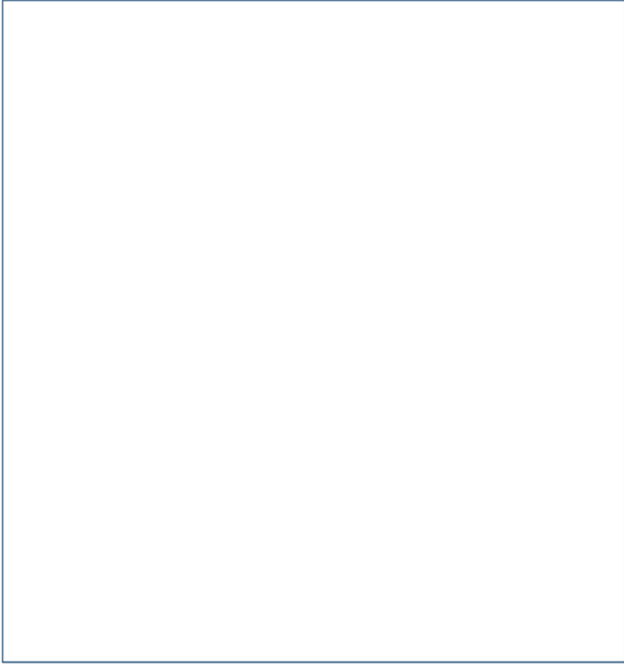
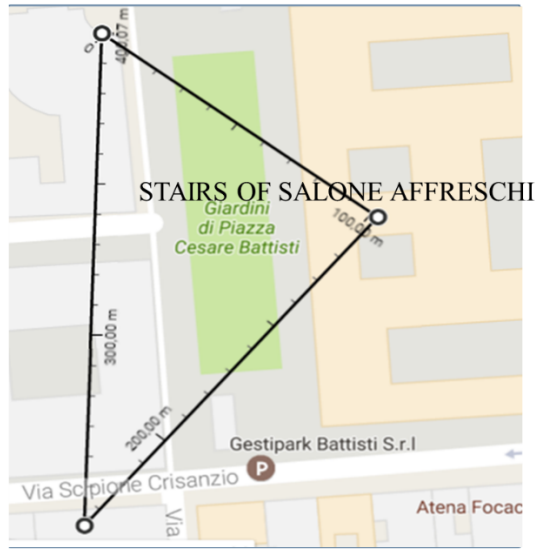


Figure 1 The empty box

ENTRANCE OF STUDENT CENTER



ENTRANCE OF DEPARTMENT

Figure 2 The Map of the Campus

(Illustrations free downloaded from Google Maps)



Figure 3 The Map of Apulia

(Illustrations free downloaded from Google Maps)



Figure 4 The Map of Italy

(Illustrations free downloaded from Google Maps)



Figure 5 The Map of The Netherlands

(Illustrations free downloaded from Google Maps)

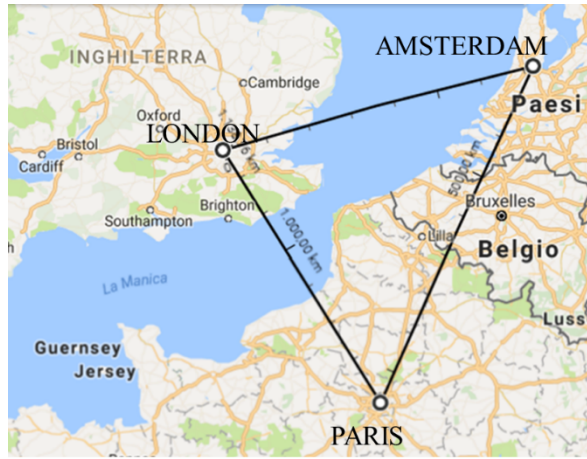


Figure 6 The Map of Northern Europe  
(Illustrations free downloaded from Google Maps)

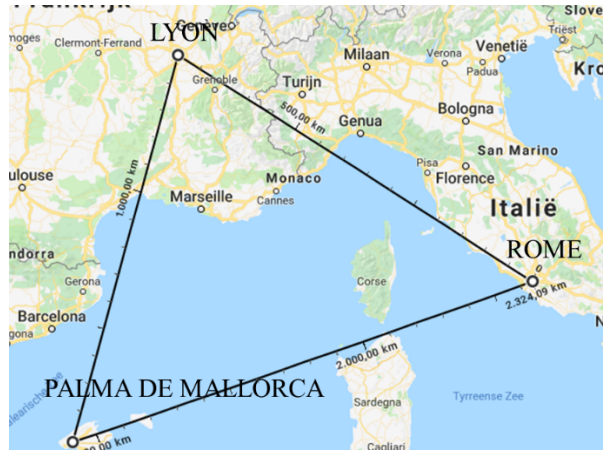


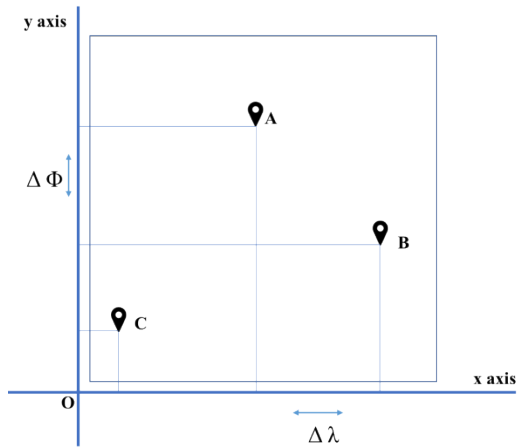
Figure 7 The Map of Southern Europe

(Illustrations free downloaded from Google Maps)



Figure 8 The Map of the World

(Illustrations free downloaded from Google Maps)



$\Delta \lambda$  is the distance between landmarks on x-axis

$\Delta \Phi$  is the distance between landmarks on y-axis

Figure 9 Example of triplet for task difficulties

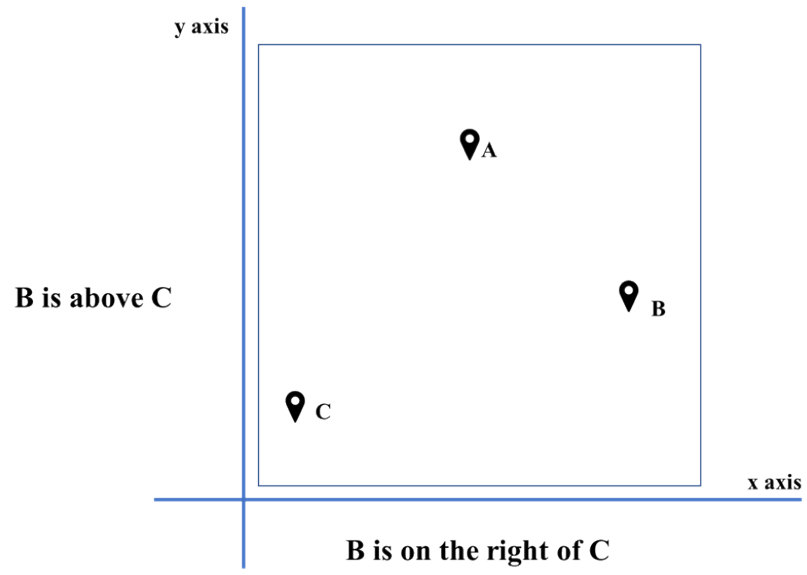


Figure 10 Categorical measurement model

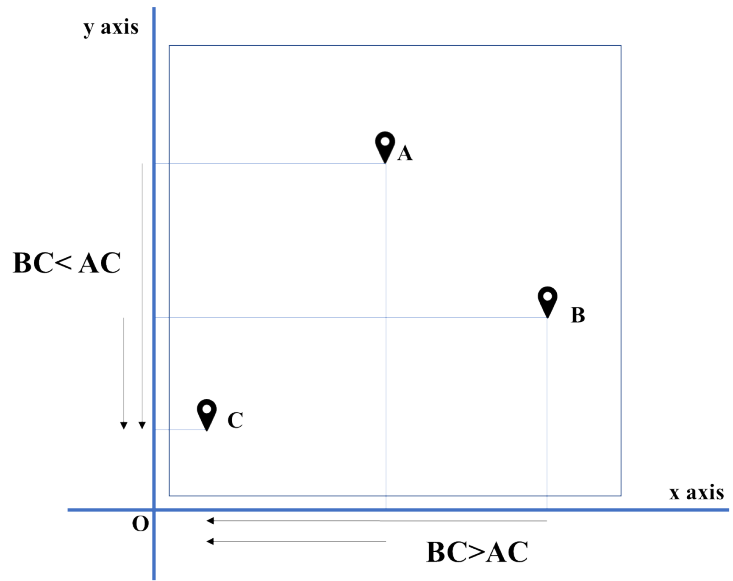


Figure 11 Better explanation of Components of Manhattan distance

## Map x Spatial Relation

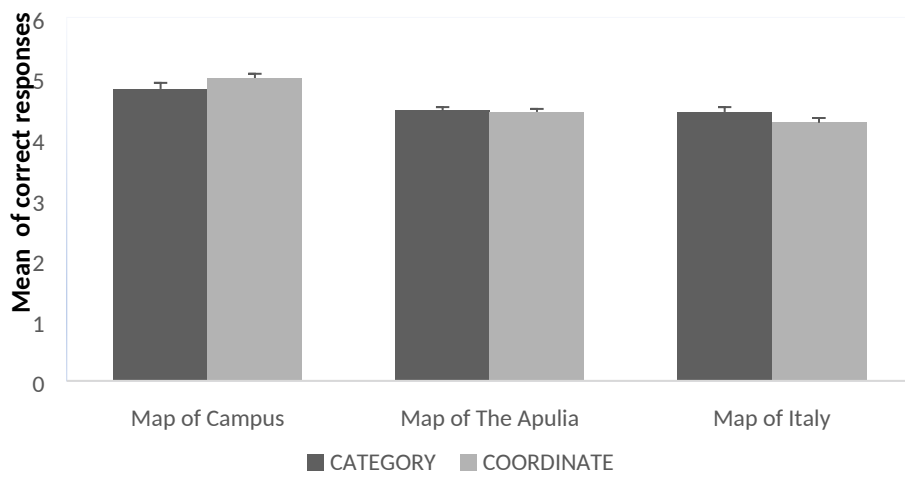


Figure 12. Mean proportion and standard error (95% Confidence Intervals) for correct responses to Map of Campus, Map of Apulia and Map of Italy for categories (dark grey bars) and coordinates (light grey bars) spatial relations

### Map x Spatial Relation

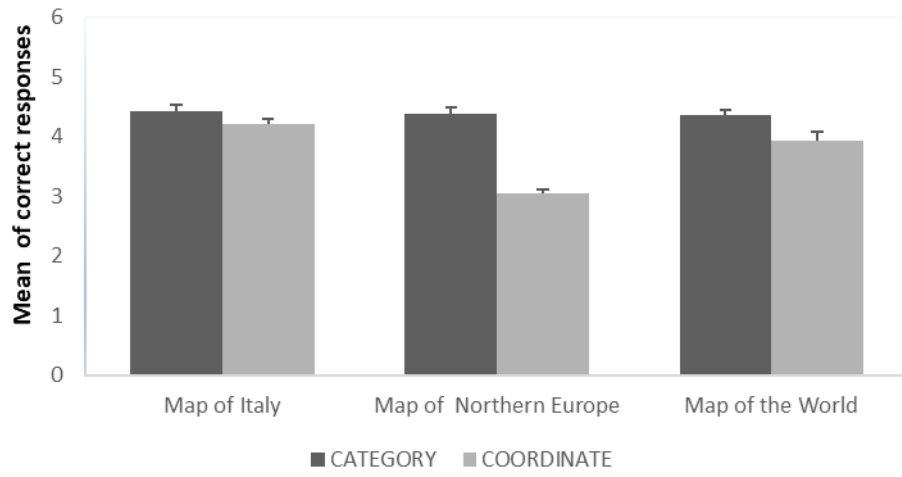


Figure 13. Mean proportion and standard error (95% Confidence Intervals) for correct responses to Map of Italy, Map of Northern Europe and Map of the World for categories (dark grey bars) and coordinates (light grey bars) spatial relations

### Accuracy across Countries

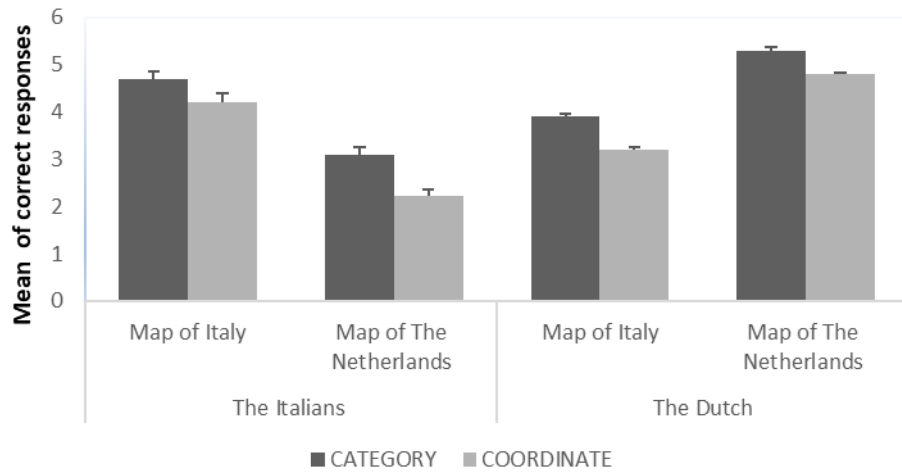


Figure 14. Mean proportion and standard error (95% Confidence Intervals) for correct responses to Map of Italy and the Map of The Netherlands for categories (dark grey bars) and coordinates (light grey bars) spatial relations, among the group of the Italians and the Dutch

## Accuracy across European Regions

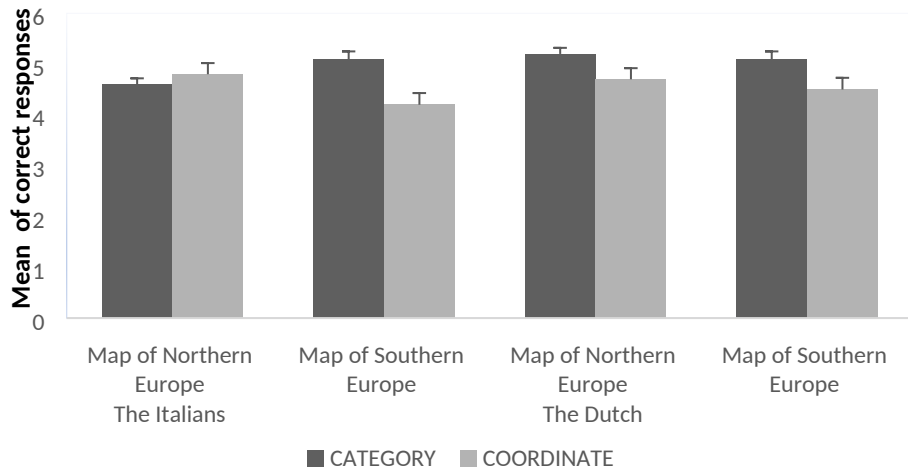


Figure 15. Mean proportion and standard error (95% Confidence Intervals) for correct responses to Map of Northern Europe and the Map of Southern Europe for categories (dark grey bars) and coordinates (light grey bars) spatial relations, among the group of the Italians and the Dutch

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<i>Landmarks</i>	Stairs of Salone Affreschi	Entrance of Student Center
Entrance of the Department	0.128 km	0.161 km
Stairs of Salone Affreschi		0.107 km

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Table 1 Map of the Campus: distance between landmarks

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<i>Landmarks</i>	Taranto	Brindisi
Bari	79km	106km
Taranto		59km

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Table 2 Map of Apulia: distance between cities

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<i>Landmarks</i>	Cagliari	Naples
Genoa	577 km	588 km
Cagliari		474 km

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Table 3 Map of Italy: distance between cities

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<i>Landmarks</i>	Den Haag	Maastricht
Groningen	167 km	270 km
Den Haag		197 km

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Table 4 Map of The Netherlands: distance between cities

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<i>Landmarks</i>	London	Paris
Amsterdam	358 km	430 km
London		344 km

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Table 5 Map of Northern Europe: distance between cities

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<i>Landmarks</i>	Lyon	Palma de Mallorca
Rome	749 km	868 km
Lyon		710 km

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Table 6 Map of Southern Europe: distance between cities

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<i>Landmarks</i>	New York	Rio de Janeiro
Cape Town	12565 km	6063 km
New York		7757 km

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Table 7 Map of the World: distance between cities

Map	Category				Sum
	x-axis		y-axis		
Map of Campus	Stairs of Salone Affreschi Entrance of Student Center		Stairs of Salone Affreschi Entrance of Student Center		9
	Entrance of the Department	1	3	Entrance of the Department	
	Stairs of Salone Affreschi		1	Stairs of Salone Affreschi	2
Map of Apulia	Taranto		Brindisi		8
	Bari	2	1	Bari	
	Taranto		1	Taranto	3
Map of Italy	Cagliari		Naples		9
	Genoa	3	1	Genoa	
	Cagliari		1	Cagliari	2
Map of The Netherlands	Den Haag		Maastricht		8
	Groningen	1	3	Groningen	
	Den Haag		1	Den Haag	1
Map of Northern Europe	London		Paris		10
	Amsterdam	1	3	Amsterdam	
	London		2	London	1
Map of Southern Europe	Lyon		Palma de Mallorca		13
	Rome	2	1	Rome	
	Lyon		3	Lyon	2
Map of the World	New York		Rio de Janeiro		10
	Cape Town	1	1	Cape Town	
	New York		2	New York	3

Table 8 Categorical task difficulty

Map	Coordinate				Sum		
	x-axis		y-axis				
Map of Campus	Stairs -Department	Stairs - Student Center	Stairs -Department	Stairs - Student Center	9		
	Department-Student Center	1	1	Department-Student Center		2	1
	Stairs -Department		3	Stairs -Department			1
Map of Apulia	Brindisi-Taranto	Brindisi-Bari	Brindisi-Taranto	Brindisi-Bari	12		
	Bari-Taranto	3	1	Bari-Taranto		1	3
	Brindisi-Taranto		2	Brindisi-Taranto			2
Map of Italy	Napoli-Genova	Naples-Cagliari	Napoli-Genova	Naples-Cagliari	10		
	Genoa-Cagliari	1	1	Genoa-Cagliari		2	1
	Napoli-Genova		3	Napoli-Genova			2
Map of The Netherlands	Maastricht-Den Haag	Groningen-Maastricht	Maastricht-Den Haag	Groningen-Maastricht	11		
	Groningen-Den Haag	3	1	Groningen-Den Haag		3	1
	Maastricht-Den Haag		2	Maastricht-Den Haag			1
Map of Northern Europe	London-Paris	Paris-Amsterdam	London-Paris	Paris-Amsterdam	18		
	Amsterdam-London	3	3	Amsterdam-London		3	3
	London-Paris		3	London-Paris			3
Map of Southern Europe	Lyon-Palma de Mallorca	Rome-Lyon	Lyon-Palma de Mallorca	Rome-Lyon	16		
	Rome-Palma de Mallorca	2	3	Rome-Palma de Mallorca		2	3
	Lyon-Palma de Mallorca		3	Lyon-Palma de Mallorca			3
Map of the World	Rio de Janeiro-New York	Cape Town-New York	Rio de Janeiro-New York	Cape Town-New York	9		
	Cape Town-Rio de Janeiro	1	2	Cape Town-Rio de Janeiro		1	1
	Rio de Janeiro-New York		1	Rio de Janeiro-New York			3

Table 9 Coordinate task difficulty

	MALE	FEMALE	Test
	(N=82)	(N=86)	
Age, years	22.01 ± 2.78	20.53 ± 0.96	<i>p</i> <0.01
Education, years	15.44 ± 1.81	15.00 ± 0.00	<i>n.s.</i>
SCHOOL SUBJECTS (avarage grade)			
Geography	7.44 ± 0.81	7.66 ± 0.67	<i>n.s.</i>
Math	7.15 ± 1.09	7.77 ± 1.07	<i>p</i> <0.01
Physics	6.95 ± 1.11	7.70 ± 1.08	<i>p</i> <0.001
Like Science Subjects	4.55 ± 1.13	4.07 ± 1.04	<i>p</i> <0.01
STUDY OF GEOGRAPHY AT SCHOOL			
Campus	-	-	-
Apulia	3.53 ± 1.58	3.57 ± 1.31	<i>n.s.</i>
Italy	3.91 ± 1.55	3.67 ± 1.22	<i>n.s.</i>
LEVEL OF FAMILIARITY WITH MAPS			
Campus	4.64 ± 0.56	3.78 ± 0.54	<i>p</i> <0.001
Apulia	3.25 ± 0.95	3.07 ± 0.87	<i>n.s.</i>
Italy	3.22 ± 0.96	2.92 ± 0.84	<i>p</i> <0.01

Table 10. Means  $\pm$  standard deviations for interval and frequencies for nominal variables, and indexes of familiarity were reported. One Way Anova for two level variables (gender) was performed

	MALE	FEMALE	Test
	(N=60)	(N=60)	
Age, years	22.31 ± 2.62	20.55 ± 0.83	<i>p</i> <0.001
Education, years	15.31 ± 1.39	15.00 ± 0.00	<i>n.s.</i>
SCHOOL SUBJECTS (average grade)			
Geography	7.45 ± 0.81	7.66 ± 0.70	<i>n.s.</i>
Math	7.16 ± 1.09	7.74 ± 1.02	<i>p</i> <0.01
Physics	6.88 ± 1.01	7.70 ± 0.80	<i>p</i> <0.001
Like Science Subjects	4.48 ± 1.01	4.03 ± 1.11	<i>p</i> <0.01
STUDY OF GEOGRAPHY AT SCHOOL			
Italy	3.88 ± 1.61	3.61 ± 1.11	<i>n.s.</i>
Northern Europe	4.01 ± 1.60	3.51 ± 1.08	<i>n.s.</i>
World	3.55 ± 1.59	3.25 ± 1.23	<i>n.s.</i>
LEVEL OF FAMILIARITY WITH MAPS			
Italy	3.09 ± 0.91	2.86 ± 0.73	<i>n.s.</i>
Northern Europe	3.16 ± 1.02	2.68 ± 0.75	<i>p</i> <0.01
World	2.75 ± 0.86	2.54 ± 0.81	<i>n.s.</i>

Table 11. Means  $\pm$  standard deviations for interval and frequen7. Means  $\pm$  standard deviations for interval and frequencies for nominal variables, and indexes of familiarity were reported. One Way Anova for two level variables (gender) was performed

	DUTCH STUDENT	ITALIAN STUDENT	Test
	(N=40)	(N=40)	
Gender, F/M	20/20	20/20	<i>n.s.</i>
Age, years	23.01 ± 3.01	24.35 ± 4.05	<i>n.s.</i>
Education, years	14.40 ± 1.89	15.90 ± 0.98	<i>n.s.</i>
SCHOOL SUBJECTS (average grade)			
Geography	9.90 ± 1.14	7.11 ± 1.60	<i>n.s.</i>
Math	6.90 ± 1.14	7.30 ± 1.18	<i>n.s.</i>
Physics	6.57 ± 1.11	7.15 ± 1.08	<i>n.s.</i>
Like Science Subjects	4.20 ± 1.60	4.18 ± 1.20	<i>n.s.</i>
WAYFINDING QUESTIONNAIRE (WQ)			
Navigation and Orientation	50.18 ± 12.9	52.33 ± 11.20	<i>n.s.</i>
Spatial Anxiety	27.02 ± 8.60	27.07 ± 7.50	<i>n.s.</i>
Distance Estimation	12.45 ± 4.08	9.48 ± 4.06	<i>p</i> <0.01

Table 12. Means  $\pm$  standard deviations for interval and frequencies for nominal variables were reported. Independent t tests for two level variables and  $\chi^2$  for frequencies were performed

	DUTCH STUDENT	ITALIAN STUDENT	Test
	(N=40)	(N=40)	
<b>STUDY OF GEOGRAPHY AT SCHOOL</b>			
Italy	2.90 ± 1.40	4.60 ± 1.40	<i>p</i> <0.01
The Netherlands	5.50 ± 1.70	2.80 ± 1.60	<i>p</i> <0.01
Northern Europe	4.90 ± 1.30	4.80 ± 1.60	<i>n.s.</i>
Southern Europe	3.80 ± 1.40	4.10 ± 1.70	<i>n.s.</i>
<b>LEVEL OF FAMILIARITY WITH MAPS</b>			
Italy	3.10 ± 0.96	3.90 ± 1.17	<i>p</i> <0.01
The Netherlands	4.20 ± 0.80	2.30 ± 1.19	<i>p</i> <0.01
Northern Europe	4.10 ± 0.70	4.30 ± 1.20	<i>n.s.</i>
Southern Europe	3.10 ± 0.93	3.30 ± 1.36	<i>n.s.</i>

Table 13. Means  $\pm$  standard deviations for interval and frequencies for nominal variables were reported. Independent t tests for two level variables were performed