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The Representation of Imagery of the City: The Impact of Studies and Imagery Ability

ALFREDO CAMPOS* *University of Santiago de Compostela*

DIEGO CAMPOS-JUANATEY *University of A Coruña*

Abstract: This study aimed to assess the impact of the type of undergraduate studies and the ability to form mental images on representations of city imagery. A total of 291 Architecture and Business Studies undergraduates participated in the study. Participants completed a 5-min task of drawing their own mental map of a city. The number of point marks, line marks, and area marks drawn and the system of representation were assessed. Business Studies undergraduates represented more point marks using a point than Architecture undergraduates, whereas the latter drew more point marks in plan and in 3D than the former. The ability to form spatial images had no influence on the number of point, line, or area marks drawn. Significant differences between women and men were observed in the 3D representations, and in the configuration.

Key words: spatial imagery, spatial cognition, mental map, cognitive map, image of the city.

The imagery of a city is a cognitive or mental map or plan that an individual has of a specific city, with its monuments, streets, districts, and so forth. The term was used by the urban architect Lynch (1960) in his book, *The Image of the City*, and is the term preferred by most architects. Lynch also referred to this concept as the *spatial imagery* of a city. Psychologists prefer to employ the term *cognitive map*, which is the term coined by Tolman (1948) in his studies on spatial orientation in rats.

In this study, the concept of *mental imagery* was used as a quasi-perceptual experience that occurs when all or part of the represented stimuli are absent (Marks, 1985). Thus, the imagery of a specific object (e.g., a piece of fruit) and the imagery of a city are formed on the basis of experience. Imagery of a city is formed by either travelling through the city or studying a map of the city, or both.

Map drawing has become a standard technique for studying cognitive mapping in adults ever since the studies of Lynch (1960). The elements of a map are still classified in accordance with the plan/diagram used by Lynch, though in some cases these may vary. These elements are: paths, edges, districts, nodes, and landmarks. Nodes are strategic points, intersections where paths normally converge. Landmarks are visually salient places that are usually used as points of reference, such as towers or hills. Paths are the important routes or lanes of transit that join reference points, such as main streets or avenues. Edges are the

*Correspondence concerning this article should be sent to: Alfredo Campos, Department of Basic Psychology, University of Santiago de Compostela, 15782 Santiago de Compostela, Spain. (E-mail: alfredo.campos@usc.es)

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boundaries between two places, such as beaches, railway tracks, walls, large avenues, and rivers. Districts are parts of the city with specific characteristics, which may be geographic, social class, or other distinguishing features.

Besides the elements described by Lynch (1960), the analysis of imagery of a city also requires measuring its configuration, that is, the extent to which distances on a map are true representations of reality. Thus, Evans and Pezdek (1980) presented the names of two pairs of places to individuals who were asked to determine which two places were the furthest apart; thereafter, the correct answers and reaction times were measured. Wilton's (1979) studies on orientation questioned individuals on the relative position of pairs of cities: for example, "Which city is the furthest north, Madrid or Washington?"

Gender

Several variables have been reported to have an impact on the cognitive mapping of cities, such as gender, age, place of work, socioeconomic status, IQ, and the habit of using maps. Gender and map drawing has been the most extensively assessed variable, and in general, differences have been found between women and men in cognitive mapping. Notwithstanding, these findings may be misleading; that is, no matter how similar the two tasks may be, the ability to understand a map or draw one is different to the ability to navigate and plan a route on a map successfully in a real setting (Coluccia & Louse, 2004).

Tests have been extensively used in most of the studies on gender differences in spatial ability. A number of meta-analytical studies (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995) on gender differences and spatial ability have found higher task performance in men than women (Blazhenkova, Becker, & Kozhevnikov, 2011; Blazhenkova & Kozhevnikov, 2009, 2010; Campos, 2012, 2014), but other studies have found no significant difference (Campos, 2009, 2013), and a few have observed higher performance in women than men (Iachini, Ruggiero, Ruotolo, & Pizza, 2008).

The findings of studies on gender differences in spatial orientation are inconsistent. Thus, several studies have found higher performance in men than women (Malinowski & Gillespie, 2001; Schmith, 1997; Waller, Knapp, & Hunt, 2001), whereas other studies have found no gender differences (Taylor & Tversky, 1992). No study has found spatial orientation to be higher in women than men (Coluccia & Louse, 2004). In the Euclidean properties of a map (direction, distance, and map-extrapolation), men were significantly better than women (Galea & Kimura, 1993).

Imagery Ability

Of the many measures of the ability to form mental imagery, the most extensively used is the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973; for a review of the studies, see McKelvie, 1995). Kosslyn and Koening (1992), and Kozhevnikov, Kosslyn, and Shepard (2005) have identified two processing styles: *visualizers* and *verbalizers.* Visualizers primarily use mental imagery, and verbalizers use linguistics signs. Visualizers tend to be object visualizers or spatial visualizers. Object visualizers have a greater ability at capturing the form, size, color, and so forth, of objects, whilst spatial visualizers are good at capturing spatial relations between objects, and prefer spatial representations or spatial transformations (Blajenkova, Kozhevnikov, & Motes, 2006b; Blazhenkova & Kozhevnikov, 2009).

Two tests are available for measuring processing styles (visualizer–verbalizer): the Individual Differences Questionnaire (IDQ; Paivio, 1971) and the Verbalizer–Visualizer Questionnaire (VVQ; Richardson, 1977). Moreover, Blajenkova et al. (2006b) designed the Object–Spatial Imagery Questionnaire (OSIQ). Thereafter, Blazhenkova and Kozhevnikov (2009) designed the Object–Spatial Imagery and Verbal Questionnaire (OSIVQ), consisting of three scales: Object Imagery, Spatial Imagery, and Verbal Scale.

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Several studies have shown that individuals with high spatial imagery scores are better at performing tasks requiring spatial imagery than individuals with low scores in spatial imagery (Campos, Pérez-Fabello, & Díaz, 2000; Coluccia, Iosue, & Brandimonte, 2007).

Type of Study

Not all professions use the same type of imagery. Several studies have shown that architects and scientists tend to use spatial imagery more than other types of imagery, which would explain why they are much better at this type of imagery than individuals from other professions (Blajenkova, Kozhevnikov, & Motes, 2006a; Kozhevnikov, Blazhenkova, & Becker, 2010; Kozhevnikov, Hegarty, & Mayer, 2002; Kozhevnikov et al., 2005; Rhoades, 1981). Good architects have high spatial ability (Alias, Black, & Gray, 2002; Mohler & Miller, 2008).

Kozhevnikov et al. (2010) applied a battery of imagery vividness and imagery rotation tests to a group composed of science, visual arts, humanities, and architecture undergraduates. This study found that scientists and architects had significantly higher spatial ability scores, whereas art undergraduates obtained higher object imagery scores. Moreover, Kawahara and Matsuoka (2013) applied the Japanese version of the OSIQ to art, welfare, agriculture, education, literature, medicine, and engineering undergraduates, and found that engineering undergraduates significantly outperformed other undergraduates in spatial imagery, and medical undergraduates had higher spatial imagery scores than art, welfare, education, and literature undergraduates.

The aim of this study was to assess gender difference between participants with high and low spatial imagery, and difference between Architecture and Business Studies (BS) undergraduates in their representation of point marks (a point, in plan, in elevation, and 3D), line marks (using a line, in plan, in elevation, and 3D), area marks (using a text, in plan, and 3D), and configuration. It was hypothesized that men with high spatial imagery, and Architecture undergraduates would have higher spatial imagery, representation of point marks, line marks, area marks, and configuration, than women with low spatial imagery, and BS undergraduates.

Method

Participants

The group consisted of 291 university undergraduates (M_{age} = 20.66 years, SD = 2.10), 135 of whom were Architecture undergraduates (77 women and 58 men), and 156 BS undergraduates (82 women and 74 men).

Materials

The Measure of the Ability to Form Spatial Mental Imagery (MASMI; Campos, 2009, 2013) was used. This test consists of an unfolded cube that participants have to mentally close in their minds prior to replying to 23 questions on the test. Each question has four responses, with two correct responses and two incorrect responses. The total score was calculated by adding the correct responses and subtracting the incorrect ones; thus, the total test score ranged from –46 to 46. Participants were given 5 min to respond to all of the questions on the test. In this study, reliability was estimated with a Cronbach's alpha of .89.

The Cronbach's alpha for the MASMI was .93, and correlated .44 ($p < .01$) with the Space Test of Primary Mental Abilities (Thurstone & Thurstone, 2002) and –.15 with the VVIQ (Campos, 2009). The MASMI also correlated .48 ($p < .01$) with the Measure of the Ability to Rotate Mental Images (Campos, 2012). The MASMI was used as the independent variable to analyze the influence of the ability to form spatial imagery in the rotation of urban maps (Dopico, González, & Campos-Juanatey, 2017). It has also been used as a dependent variable (Campos, 2014; Pérez-Fabello, Campos, & Felisberti, 2018).

Procedure

In their normal classrooms, the 291 second-year undergraduates (135 Architecture undergraduates and 156 BS undergraduates), were

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given an A3-sized sheet of paper (29.7 × 42.0 cm), and were allowed 5 min to draw their own image of the city of A Coruña, Spain. Participants were instructed that their drawings should include the important buildings, streets, districts, and so forth. All of the participants knew the city and had lived there for 2–3 years. Thereafter, two judges analyzed each drawing, and the results of the two groups (Architecture and BS)—in terms of point marks, line marks, area marks, and configuration—were compared.

Participants were classified as high or low in spatial imagery ability according to whether their mean was above or below the group mean corresponding to their specific degree. In other words, the mean for each Architecture undergraduate was compared to the mean for the group of Architecture undergraduates, and the mean for each BS undergraduate was compared with the mean for all BS undergraduates. The mean MASMI score obtained by Architecture undergraduates was 18.51 (SD = 10.53), and the mean for BS undergraduates was 7.63 (SD = 8.87).

Having gathered the data, the results were analyzed using Lynch's (1960) model of the elements of the imagery of a city, which were grouped into three types according to their dimensions: point marks, line marks, and area marks. The configuration was also measured (Lázaro, 2000). The grouping of the elements into three categories was undertaken following the rules for selecting and classifying elements used in studies of cartographic maps, that is, the point marks (equivalent to the sum of the node and landmark categories of Lynch), line marks (equivalent to the sum of the categories of paths and edges described by Lynch), and area marks (equivalent to Lynch's category of districts). The configuration is not an element in its own right, but rather the structure or schema relating all of the other elements. The isolated points of reference and routes are useless for planning a journey, and a structure is required to relate them: That structure is the configuration (Campos-Juanatey, Dopico, & González, 2017).

The number of elements for each category in each drawing was calculated and the judges considered the way they had been represented. We computed the point marks represented: (a) by a point, (b) in plan (i.e., the representation of the horizontal distribution of an area; e.g., the plan of the distribution of galleries in a museum), (c) in elevation (i.e., the representation of vertical elements; e.g., the facade of a building or several facades of buildings in a street or neighborhood), and (d) in 3D. We computed the line marks represented: (a) by a line, (b) in plan, (c) in elevation, and (d) in 3D. Finally, we computed the area marks represented by: (a) text, (b) in plan, and (c) in 3D.

The configuration was assessed by two independent judges. The score used for analysis was the mean score of the judges. The configuration was evaluated on a 0 to 10 scale, where 0 indicated a *poor configuration*, and 10 a *good configuration*. The judges' scoring was based on a detailed list of criteria. The following factors were evaluated: (a) the degree of similarity between the undergraduate's drawing and the technical representation of the entire city; (b) how well the drawing maintained the position among the different elements represented and the distances between them, regardless of the scale of the drawing; (c) the number of elements represented (drawing only two elements gives a 0 configuration given that without knowing the scale of the drawing, it is impossible to ascertain if the distance between them is correct); (d) how well the drawing exhibited a uniform configuration (drawings that did not exhibit a uniform configuration, with some parts being more proportional than others, were assigned a global configuration, i.e., a mean score of the configuration of the parts) and the configuration between the different parts of the drawing; and (e) the drawing's degree of complexity and detail (drawings based on simplifications or abstractions of the shape of the city were awarded lower scores according to the degree of deformity). The correlation between the judges was .94 ($p < .001$).

The investigation was conducted in accordance with ethical rules contained in the Declaration of Helsinki of 1964, and written informed consent was obtained from each participant. All of the undergraduates freely

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volunteered to participate in the study and were not incentivized. Ethical approval was not required for this study in accordance with the national and institutional guidelines.

Statistical Analysis

To determine intra-judge concordance in the evaluation of the configurations, a Pearson's correlation was performed. The reliability of the MASMI in this study was estimated by a Cronbach's alpha. To establish significant differences in imagery ability between women and men, a Student's *t* test was conducted for independent groups. In addition, another Student's *t* test was performed to determine significant differences in imagery ability (MASMI) between Architecture and BS undergraduates. To establish the spatial imagery ability of each of the two groups—Architecture and BS undergraduates—the mean for each group was computed. A multivariate analysis of variance (MANOVA) was performed to evaluate differences between high and low spatial imagery ability (MASMI) in women and men, and between Architecture and BS undergraduates, in each of the four ways of representing the point marks (using a point, in plan, in elevation, or in 3D), in the four ways of representing the line marks (using a line, in plan, in elevation, or in 3D), and the area marks (using text, in plan, or in 3D). Finally, an analysis of variance (ANOVA) was conducted to assess differences between the participants with high or low spatial imagery (MASMI), between women and men, and between Architecture and BS undergraduates in the configuration.

Results

Practically all of the participants used the same representation technique for drawing the entire map, that is, a contour map without any altimetric information, with different representations of the point, line, and area marks.

Imagery Ability (MASMI)

To determine significant differences between Architecture and BS undergraduates, a Student's *t* test was performed, and Architecture undergraduates ($M = 18.51$, $SD = 10.53$) were found to have significantly higher imagery ability (MASMI) than BS undergraduates ($M = 7.63$, $SD = 8.87$), $t(299) = 9.73$, $p < .001$. To examine significant differences between women and men in imagery ability (MASMI), a Student's *t* test was conducted, but no significant differences in gender were observed, $t(298) = .14$, $p = .89$.

Point Marks

The first step was to examine difference between Architecture and BS undergraduates, between undergraduates with high or low spatial imagery ability, and between women and men in the number of point marks and the way they were represented by carrying out a MANOVA of 2 (Spatial Imagery) × 2 (Gender) × 2 (Type of Study). The dependent variables were the number of point marks represented using a point, in plan, in elevation, or in 3D. The means and standard deviations of the groups are shown in Table 1.

The results of the MANOVA showed significant differences in the representation of point marks between Architecture and BS undergraduates, Wilks's lambda = .64, $F(4, 280) = 39.58$, $p < .001$, $\eta_p^2 = .36$, power = 1. The univariate analysis found significant differences between Architecture and BS undergraduates in all of the point mark representations, that is, in the number of elements represented using a point, in plan, in elevation, and in 3D. BS undergraduates ($M = 2.68$, $SD = 2.80$) represented more point marks using a point than Architecture undergraduates ($M = 0.84$, $SD = 1.69$), $F(1, 283) = 42.79$, $p < .001$, $\eta_p^2 = .13$, power = 1. In comparison, Architecture undergraduates represented more point marks using plan representations ($M = 2.90$, $SD = 2.34$) than BS undergraduates ($M = 1.13$, $SD = 1.73$), $F(1, 283) = 49.03$, $p < .001$, $\eta_p^2 = .15$, power = 1. The number of point marks represented in elevation were higher in BS ($M = 0.65$, $SD = 0.97$) than in Architecture undergraduates ($M = 0.19$, $SD = 0.79$), $F(1, 283) = 18.92$, $p < .001$, $\eta_p^2 = .06$, power = .99. As for the

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Table 1 Means and standard deviations of representations of point marks according to type of study, spatial imagery ability (high or low), and gender

	Representations of point marks									
	A point		In plan		In elevation		In 3D		Total	
Groups	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Architecture	0.84	1.69	2.90	2.34	0.19	0.79	0.58	1.27	4.50	2.40
BS	2.68	2.80	1.13	1.73	0.65	0.97	0.04	0.35	4.57	2.39
High imagery	1.86	2.75	2.22	2.36	0.46	0.88	0.34	0.97	4.91	2.61
Low imagery	1.80	2.32	1.73	2.08	0.42	0.95	0.26	0.91	4.23	2.16
Women	1.61	2.31	2.06	2.30	0.38	0.83	0.21	0.67	4.34	2.34
Men	2.09	2.73	1.83	2.11	0.50	1.02	0.39	1.18	4.80	2.43
Total	1.83	2.52	1.96	2.22	0.44	0.92	0.29	0.94	4.54	2.39

representation of 3D elements, Architecture undergraduates represented more 3D elements ($M = 0.58$, $SD = 1.27$) than did BS undergraduates ($M = 0.04$, $SD = 0.35$), $F(1, 283) = 26.36$, $p < .001$, $\eta_p^2 = .09$, power = 1.

The results also revealed significant differences between women and men in the representation of point marks, Wilks's lambda = .97, $F(4, 280) = 2.34$, $p = .05$, $\eta_p^2 = .36$, power = 1. The univariate analysis examining gender differences in representation techniques showed differences between women and men in the representation of point marks in 3D, with men ($M = 0.39$, $SD = 1.18$) representing more point marks in 3D than women ($M = 0.21$, $SD = 0.67$), $F(1, 283) = 3.93$, $p < .05$, $\eta_p^2 = .01$, power = .51. No gender differences were observed in the remaining ways of representing the point marks: using a point, $F(1, 283) = 1.98$, $p = .16$, $\eta_p^2 = .01$, power = .29; in plan, $F(1, 283) = 0.47$, $p = .49$, $\eta_p^2 = .01$, power = .11; and in relief, $F(1, 283) = 0.68$, $p = .41$, $\eta_p^2 = .01$, power = .13. Likewise, no significant differences were found in the representation of point marks between participants with high or low spatial imagery, Wilks's lambda = .98, $F(4, 280) = 1.62$, $p = .17$, $\eta_p^2 = .02$, power = .50.

The first-order interactions were not significant: type of study and gender, Wilks's lambda = .98, $F(4, 280) = 1.64$, $p = .17$, $\eta_p^2 = .02$, power = .50; type of study and spatial imagery ability, Wilks's lambda = .99, $F(4, 280) = 1.62$, $p = .53$, $\eta_p^2 = .01$, power = .25; and spatial imagery ability and gender, Wilks's lambda = .99, $F(4, 280) = 0.74$, $p = .56$, $\eta_p^2 = .01$, power = .23. The second-order interaction—type of study, gender, and spatial imagery ability—was not significant either, Wilks's lambda = 1, $F(4, 280) = 0.09$, $p = .99$, $\eta_p^2 = .01$, power = .07.

Line Marks

The second step was to determine significant differences in the number of line marks and the way of representing them (in the representation of imagery of a city), between Architecture and BS undergraduates, between high and low spatial imagery ability, and between women and men. To confirm this hypothesis, a MANOVA of 2 (Spatial Imagery) × 2 (Gender) × 2 (Type of Study) was carried out. The dependent variables were the number of lineal elements represented using a line, in plan, in elevation, and in 3D. The means and standard deviations are shown in Table 2.

The results of the MANOVA revealed significant differences in the representation of lineal elements between Architecture and BS undergraduates, Wilks's lambda = .87, $F(4, 280) = 10.16$, $p < .001$, $\eta_p^2 = .13$, power = 1. The univariate analysis found significant differences between Architecture and BS undergraduates in the representations using

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Table 2 Means and standard deviations of representations of line marks according to type of study, spatial imagery ability (high or low), and gender

	Representations of lineal marks									
	A line		In plan		In elevation		In 3D		Total	
Groups	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Architecture	2.01	1.65	1.13	1.68	0.01	1.09	0.02	0.19	3.17	1.89
BS	1.39	1.07	0.57	1.31	0.04	0.22	0.01	0.11	2.17	1.53
High imagery	1.76	1.54	0.89	1.51	0.02	0.12	0.03	0.21	2.72	1.79
Low imagery	1.61	1.28	0.79	1.53	0.03	0.21	0.01	0.08	2.56	1.76
Women	1.58	1.37	0.85	0.51	0.04	0.23	0.03	0.21	2.57	1.77
Men	1.80	1.44	0.81	1.54	0.01	0.01	0.01	0.01	2.72	1.78
Total	1.68	1.40	0.83	0.52	0.02	0.17	0.02	0.15	2.63	1.77

lines and in plan. The Architecture undergraduates ($M = 2.01$, $SD = 1.65$) obtained more line marks represented by a line than BS undergraduates ($M = 1.39$, $SD = 1.07$), $F(1, 283) = 16.16$, $p < .001$, $\eta_p^2 = .05$, power = .40. Architecture undergraduates ($M = 1.13$, $SD = 1.68$) also had more line marks represented in plan than BS undergraduates ($M = 0.57$, $SD = 1.31$), $F(1, 283) = 9.02$, $p < .01$, $\eta_p^2 = .03$, power = .85. No significant differences were observed between Architecture and BS undergraduates in the representation of line marks in elevation, $F(1, 283) = 1.91$, $p = .17$, $\eta_p^2 = .17$, power = .28, or in 3D, $F(1, 283) = 0.09$, $p = .77$, $\eta_p^2 = .01$, power = .06.

Gender had no influence on the representation of line marks, Wilks's lambda = .97, $F(4, 280) = 2.27$, $p = .06$, $\eta_p^2 = .03$, power = .66.

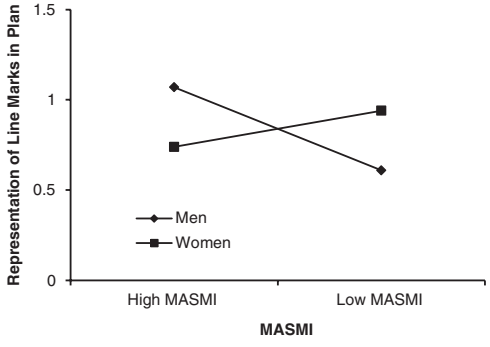

Figure 1 Interactions between gender and the ability to form spatial imagery in the representation of line marks in plan.

The imagery ability also had no influence on representation of line marks, Wilks's lambda = .99, $F(4, 280) = 0.88$, $p = .48$, $\eta_p^2 = .01$, power = .28. The interactions between type of study and gender, Wilks's lambda = .99, $F(4, 280) = 1.02$, $p = .40$, $\eta_p^2 = .01$, power = .32, and between type of study and the ability to form spatial imagery, Wilks's lambda = .98, $F(4, 280) = 1.46$, $p = .22$, $\eta_p^2 = .02$, power = .45, were not significant. However, there was a significant interaction between gender and the ability to form spatial imagery, Wilks's lambda = .97, $F(4, 280) = 2.35$, $p = .05$, $\eta_p^2 = .03$, power = .68. Univariate analysis showed a significant interaction between gender and the ability to form spatial imagery in the representation of line marks in plan, $F(1, 283) = 4.09$, $p = .04$, $\eta_p^2 = .01$, power = .52 (see Figure 1). The second-order interaction—type of study, gender, and the ability to form spatial imagery—was not significant, Wilks's lambda = .99, $F(4, 280) = 52$, $p = .72$, $\eta_p^2 = .01$, power = .17.

Area Marks

Moreover, significant differences in the number of area marks and ways of representing the imagery of a city were evaluated between Architecture and BS undergraduates, between high and low spatial imagery ability, and between women and men. To confirm this hypothesis, a MANOVA of 2 (Spatial Imagery) × 2 (Gender) × 2 (Type of Study) was

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Table 3 Means and standard deviations of representations of area marks according to type of study, spatial imagery ability (high or low), and gender

	Representations of area marks							
	In text		In plan		In 3D		Total	
Groups	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Architecture	0.80	1.18	2.05	1.94	0.03	0.17	2.90	1.83
BS	1.84	1.93	0.44	0.97	0.01	0.11	2.35	1.85
High Imagery	1.34	1.85	1.29	1.72	0.02	0.15	2.72	1.90
Low Imagery	1.37	1.59	1.10	1.69	0.02	0.14	2.51	1.82
Women	1.32	1.79	1.06	1.69	0.03	0.18	2.49	2.00
Men	1.40	1.60	1.33	1.72	0.01	0.09	2.73	1.68
Total	1.36	1.70	1.19	1.70	0.02	0.14	2.60	1.86

performed. The dependent variables were the number of area marks represented using text, in plan, and in 3D. The means and standard deviations of the groups are shown in Table 3.

The results of the MANOVA revealed significant differences in the representation of area marks between Architecture and BS undergraduates, Wilks's lambda = .75, $F(3, 281) = 31.45$, $p < .001$, $\eta_p^2 = .25$, power = 1. The univariate analysis found significant differences between Architecture and BS undergraduates in the representation of area marks using text and in plan. The BS undergraduates ($M = 1.84$, $SD = 1.93$) had more area marks represented using text than Architecture undergraduates ($M = 0.80$, $SD = 1.18$), $F(1, 283) = 30.95$, $p < .001$, $\eta_p^2 = .10$, power = 1. However, Architecture undergraduates had more elements represented in plan ($M = 2.05$, $SD = 1.94$) than BS undergraduates ($M = 0.44$, $SD = 0.97$), $F(1, 283) = 84.67$, $p < .001$, $\eta_p^2 = .23$, power = 1. In the 3D representation, no significant difference was observed between Architecture and BS undergraduates, $F(1, 283) = 0.06$, $p = .43$, $\eta_p^2 = .01$, power = .13.

No significant differences were found between women and men in the representation of area marks, Wilks's lambda = .98, $F(3. 281) = 2.10$, $p = .10$, $\eta_p^2 = .02$, power = .53. Neither were there significant differences between the high and low spatial imagery in techniques for representing area marks, Wilks's lambda = .99, $F(3, 281) = 0.16$, $p = .92$, $\eta_p^2 = .01$, power = .08. Similarly, there were no significant first-order interactions: type of study and gender, Wilks's lambda = .99, $F(3, 281) = 0.96$, $p = .41$, $\eta_p^2 = .01$, power = .26; type of study and ability to form spatial imagery, Wilks's lambda = .99, $F(3, 281) = 0.46$, $p = .71$, $\eta_p^2 = .01$, power = .14; nor between gender and ability to form spatial imagery, Wilks's lambda = .99, $F(3, 281) = 0.37$, $p = .78$, $\eta_p^2 = .01$, power = .12. The second-order interaction was not significant: type of study, gender, and ability of form spatial imagery, Wilks's lambda = .99, $F(3, 281) = 0.66$, $p = .58$, $\eta_p^2 = .01$, power = .19.

Configuration

Finally, significant differences in configuration (representations of the imagery of a city) were observed between different spatial imagery abilities, gender, and type of study. To corroborate this hypothesis, an ANOVA of 2 (Spatial Imagery) × 2 (Gender) × 2 (Type of Study) was performed with the scores in the configuration as the dependent variable. The means and standard deviations are shown in Table 4.

The results of the ANOVA found significant differences in configuration between Architecture and BS undergraduates. The former obtained a higher score in configuration ($M = 3.39$, $SD = 2.62$) than the latter ($M = 2.02$, $SD = 1.96$), $F(1, 283) = 25.61$, $p < .001$, $\eta_p^2 = .08$, power = 1. Gender also influenced configuration: men obtained higher

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Table 4 Means and standard deviations of representations of configuration according to type of study, spatial imagery ability (high or low), and gender

Groups	*M*	*SD*
Architecture	3.39	2.62
BS	2.02	1.96
High imagery	2.81	2.37
Low imagery	2.53	2.41
Women	2.41	2.49
Men	2.96	2.24
Total	2.66	2.39

configuration scores ($M = 2.96$, $SD = 2.24$) than women ($M = 2.41$, $SD = 2.49$), $F(1, 283) = 5.53$, $p = .01$, $\eta_p^2 = .02$, power = .65. The ability to perform spatial imagery was not significant, $F(1, 283) = 0.50$, $p = .48$, $\eta_p^2 = .01$, power = .11. The first-order interactions were not significant: type of study and gender, $F(1, 283) = 0.57$, $p = .45$, $\eta_p^2 = .01$, power = .12; type of study and spatial imagery ability, $F(1, 283) = 0.14$, $p = .71$, $\eta_p^2 = .01$, power = .07; gender and spatial imagery ability, $F(1, 283) = 0.18$, $p = .67$, $\eta_p^2 = .01$, power = .07. The interactions between the three variables—type of study, gender, and spatial imagery ability—were not significant, $F(1, 283) = 1.94$, $p = .17$, $\eta_p^2 = .01$, power = .24.

Discussion

The first analysis, involving the correlation between the two judges, obtained a very high correlation with significance being one to a thousand, indicating that intra-judge coherence was very high. The Cronbach's alpha for the MASMI was very high, comparable to the .93 obtained by Campos (2009, 2013) in both studies. This underscored the high reliability of the measure of spatial imagery.

Imagery Ability

Architecture undergraduates were found to have higher spatial imagery abilities than BS undergraduates. This result is in agreement with the findings of Campos-Juanatey, Pérez-Fabello, and Campos (2017). These differences in spatial imagery ability can explain the differences in the mental map of a city between Architecture and BS undergraduates. There is a relation between spatial imagery ability and performance in science, technology, engineering, and mathematics (Hegarty & Kozhevnikov, 1999; Mohler & Miller, 2008).

The results of the present study, in which Architecture undergraduates outperformed BS undergraduates, can be interpreted in terms of different types of processing. As shown by the work of Kozhevnikov et al. (2010) and Kawahara and Matsuoka (2013), Architecture undergraduates use a type of processing where spatial imagery and imagery rotation predominate, which would explain why they are better at performing tasks requiring spatial abilities than BS undergraduates. It would be interesting to analyze if the difference in spatial imagery ability between Architecture and BS undergraduates had existed prior to the students' admittance to university, or if it was a product of the university education.

No significant differences were observed between women and men on the MASMI, which confirmed previous studies (Campos, 2009, 2012), given that the MASMI is a test measuring spatial imagery, not imagery rotation, and the difference between women and men was mainly in the imagery-rotation tests (see Campos, 2014, for a review).

Point Marks

The univariate analysis showed that BS undergraduates represented more point marks with a point and in elevation than Architecture undergraduates. In comparison, the latter had more point marks represented at ground level and in 3D than the former. Architecture undergraduates employed more complex representation techniques, such as representing in plan instead of using a point, and in 3D rather than in elevation. This may be due to the training of Architecture undergraduates in designing maps and developing representation techniques, whereas BS undergraduates

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undergo other types of studies (Blajenkova et al., 2006a; Kozhevnikov et al., 2002, 2005, 2010; Rhoades, 1981). Good architects have high spatial ability (Alias et al., 2002; Mohler & Miller, 2008). Sorby and Baartmans (1996) and Ursyn (1997) have also underscored that architects should have heightened spatial ability to undertake tasks such as making maps by applying the most appropriate techniques.

The statistical results showed significant differences between women and men in the representation of point marks in 3D; that is, men scored higher than women. Three-dimensional representations are related to spatial ability, and in previous studies, men have scored higher in this ability (Blazhenkova et al., 2011; Blazhenkova & Kozhevnikov, 2009, 2010; Campos, 2012, 2014).

Line Marks

The univariate analysis revealed that Architecture undergraduates employed more line mark representations using a line and in plan than BS undergraduates. This confirms the findings of previous studies that found differences in spatial ability between architecture undergraduates and other types of studies (Blajenkova et al., 2006a; Kozhevnikov et al., 2002, 2005, 2010; Rhoades, 1981). Regardless of the group examined, fewer line marks were represented in elevation, in 3D, and in lineal representations than in plan, which indicated that these representation techniques for drawing line marks were not frequently used.

A significant interaction was observed in the number of lineal representations in plan between gender and the ability to form mental imagery. Men with high ability to form mental imagery had a greater number of lineal representations in plan than women with high ability to form mental imagery. In comparison, women with low ability to form mental imagery had more lineal representations in plan than men with low ability to form mental imagery. This result is striking in terms of the performance of women with low ability to form mental imagery and the number of lineal representations on plans. Until now, men with high ability to form mental imagery were found to outperform women in spatial activities, but women with low ability to form mental imagery have not been reported to surpass men. This result is interesting and should be further corroborated in future studies.

The fact that women with high or low spatial imagery ability exhibit behavior different to men with high or low spatial imagery ability may be explained by different information processing in women and men with high spatial imagery ability to that of women and men with low spatial imagery ability. An alternative explanation is that men with high spatial imagery ability have higher motivation than women, and men with low spatial imagery ability have a lower motivation than women with low spatial imagery ability.

Area Marks

Univariate analysis revealed that BS undergraduates represented more area marks using text than Architecture undergraduates, whereas the latter represented more area marks in plan than the former. Architecture undergraduates tended to employ a more complex technique of representation, such as representation in plan instead of using text. A plausible explanation may be owing to the training received by architecture undergraduates in designing maps and developing representation techniques, a finding corroborated in studies showing that architects have high spatial ability (Alias et al., 2002; Mohler & Miller, 2008). BS undergraduates resorted to creating a map in the best way that they knew, that is, writing; whereas, Architecture undergraduates tended to represent the map elements by drawing the elements in plan, with the added difficulty of having to define an extension and the approximate limits of a superficial element. This would confirm the advantage of architecture undergraduates over other types of undergraduates in navigating maps (Blajenkova et al., 2006a; Kozhevnikov et al., 2002, 2005, 2010; Rhoades, 1981).

Configuration

The results indicated significant difference in the configuration between Architecture

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undergraduates and BS undergraduates. The former obtained higher scores in configuration than the latter. This result was in agreement with studies underscoring the superiority of architecture undergraduates over other undergraduates in navigating maps (Alias et al., 2002; Blajenkova et al., 2006a; Kozhevnikov et al., 2002, 2005, 2010; Mohler & Miller, 2008; Rhoades, 1981).

Gender was found to influence the configuration, with men obtaining higher scores in configuration than women. This result substantiated the findings of previous studies showing higher performance in configuration of men (Galea & Kimura, 1993; Malinowski & Gillespie, 2001; Schmith, 1997; Waller et al., 2001).

We propose new studies to analyze gender differences during the first and final years at university in 3D representations and configurations. If there were differences between women and men in both years, we would recommend training programs in 3D representations and configurations during the first year of university education.

Conclusions

In conclusion, our study has revealed the following:

1. Architecture undergraduates had higher imagery abilities than BS undergraduates.
2. Architecture undergraduates were superior in all of the point mark representations than BS undergraduates (in plan, in elevation, and in 3D). Men represented more 3D point marks than women.
3. Architecture undergraduates depicted more line mark representations using a line and plans than BS undergraduates.
4. Men with high mental imagery ability had more linear representations and plans than women with high mental imagery ability. However, women with low mental imagery ability depicted more lineal representations and plans than men with low mental imagery ability.
5. BS undergraduates tended to represent area marks using text, whereas Architecture undergraduates tended to represent them using plans.
6. The configuration of architecture undergraduates was greater as compared to BS undergraduates, and greater for men than for women.

Conflicts of Interest

There are no conflicts of interest that need to be disclosed.

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