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RESEARCH REPORT

Cognitive styles and mental rotation ability in map learning

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Abstract In inspecting, learning and reproducing a map, a wide range of abilities is potentially involved. This study examined the role of mental rotation (MR) and verbal ability, together with that of cognitive styles in map learning. As regards cognitive styles, the traditional distinction between verbalizers and visualizers has been taken into account, together with a more recent distinction between two styles of visualization: spatial and object. One hundred and seven participants filled in two questionnaires on cognitive styles: the Verbalizer–Visualizer Questionnaire (Richardson in J Ment Imag 1:109–125, 1977) and the Object-Spatial Imagery Questionnaire (Blajenkova et al. in Appl Cogn Psych 20:239–263, 2006), performed MR and verbal tests, learned two maps, and were then tested for their recall. It was found that MR ability and cognitive styles played a role in predicting map learning, with some distinctions within cognitive styles: verbal style favoured learning of one of the two maps (the one rich in verbal labels), which in turn was disadvantaged by the adoption of spatial style. Conversely, spatial style predicted learning of the other map, rich in visual features. The discussion focuses on implications for cognitive psychology and everyday cognition.

Keywords Map learning · Cognitive style · Mental rotation

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Introduction

During everyday life, we are quite frequently engaged in using various kinds of maps—for example, when we visit a new city, drive to an unfamiliar destination, or move inside a complex building (e.g., a museum or a shopping center). What do we focus on when we examine a map? We may mainly consider verbal labels, or focus on visual characteristics and invest our attention and processing resources on shapes, colors, and other visual elements. Alternatively, we may focus on spatial properties, creating a schematic representation of important landmarks, their respective positions, and the streets connecting them. Another question is which cognitive abilities we use to interpret and memorize maps. It is probable that the visual and spatial components of working memory (Logie 1995) and spatial ability—generally defined as 'the skill in representing, transforming, generating, and recalling symbolic not linguistic information' (Linn and Petersen 1985, p. 1482)—are massively involved in map processing. Several subcomponents have been identified within spatial ability (Carroll 1993; McGee 1979), defined by Linn and Petersen (1985) and Voyer et al. (1995) as spatial perception, spatial visualization, and mental rotation (MR). The current study aims at investigating the distinct role of verbal, object, and spatial cognitive styles, and of verbal and spatial ability in affecting map learning. Regarding spatial ability, we consider only one spatial factor—mental rotation (Linn and Petersen 1985; McGee 1979)—for two reasons: first, mental rotation is the most frequently investigated spatial factor in the field of environmental learning, and several studies have demonstrated its connections with sense of direction (Pazzaglia and De Beni 2001), spatial language processing (Meneghetti et al. 2011), and survey representation (Pazzaglia and De Beni 2006); second, as we are interested in seeking specific relations between map learning, cognitive styles, and ability, we chose mental rotation for its relation with the spatial visualizer style (Blajenkova et al. 2006). In this way, we could establish whether cognitive styles and abilities have specific effects on the performance of cognitive complex tasks even when they are strongly correlated with each other. To assess mental rotation proficiency, we used the Mental Rotation Test (MRT)—a measure of mental rotation ability devised by Vandenberg and Kuse (1978) on the basis of the stimuli used by Shepard and Metzler (1971)—which has been used in many studies and is widely validated.

Cognitive styles: a definition

Cognitive styles are conceptualized as individual modes of acquiring and processing information which regulate an individual's cognitive functioning (Klein 1951). They are quite stable over time and are generalized to similar tasks (Jonassen and Brabowski 1993), affecting attitudes, preferences, strategies, and ways of perceiving, learning, thinking, and remembering (Messick 1976). Although they are related with cognitive abilities, they are not identifiable simply with them. Rather, cognitive styles are thought 'to serve as high-level heuristics that organize lower-level strategies, operations, and propensities—often including abilities—in such complex sequential processes as problem solving and learning' (Messick 1976, p. 9). As preferred forms of cognitive regulation (Holzman and Klein 1954), cognitive styles are considered as distinct predictors of performance (Kozhevnikov 2007) and differ from cognitive abilities because they refer to preferential ways of processing information rather than to capabilities (Mayer and Massa 2003).

One of the most frequently studied cognitive styles is that of distinguishing people who prefer using imagery and visual stimuli (*visualizers*) from those who prefer verbal information (*verbalizers*) (Paivio 1971; Richardson 1977). More recently, Kozhevnikov et al. (2002; 2010) extended the visualizer dimension and proposed a further distinction between two kinds of visualizers, called 'spatial' and 'object.' Spatial visualizers prefer to manipulate schematic and spatially organized images, paying attention mainly to locations and spatial relationships among objects, like imaging spatial transformations. Object visualizers prefer to work with static images and pay more attention to pictorial stimuli such as shape, size, color, and brightness, and create vivid, concrete images. Generally, they find it difficult to handle abstract graphic representations (Kozhevnikov et al. 2005).

The occurrence of these two styles has been demonstrated by research in both the cognitive and neuroimaging domains. Blajenkova et al. (2006) and Kozhevnikov et al. (2005) found that object and spatial visualizers differ in the Mental Rotation Test (MRT) (Vandenberg and Kuse 1978). It emerged that spatial visualizers were more accurate and faster than object visualizers in performing the MRT. Conversely, object visualizers outperformed the spatial ones in a visual-ability test, the degraded pictures task (Ekstrom et al. 1976).

The distinction between spatial and object visualizers is based on identifying two separate neural systems, involved in the processing of visual and spatial information, respectively: a *ventral* system—processing the shape and color of objects—and a *dorsal* system—processing localization and spatial attributes (Kosslyn and Koenig 1992; Smith et al. 1995). Motes and Kozhevnikov (2006) and Motes et al. (2008) found distinct, and coherent, patterns of neural activation by object and spatial visualizers during the processing of visual and spatial information. On the basis of the findings reviewed above, we expected that, when working with maps, individuals with spatial cognitive style would focus their attention and processing resources on spatial characteristics, with consequently better learning of spatial properties with respect to object visualizers. However, we cannot exclude the possibility that map learning also depends on verbalizer style. Verbalizers may focus attention on the names of monuments and streets and use them for memorization.

Cognitive variables in map processing

Few studies have so far addressed the issue of which cognitive variables are implied in map processing. In two experiments, Coluccia (2008) examined whether and to what extent working memory was necessary for map processing. Working Memory (WM) is considered a temporary memory system for encoding, maintaining, and manipulating verbal and visuo-spatial information. In the model of Baddeley and Hitch (1974), two slave systems process, respectively, verbal and visuo-spatial information coordinated by a central executive with attentive functions. In the first study, which adopted a dual-task paradigm, it was found that a spatial concurrent task (spatial tapping) impaired map learning more than a verbal concurrent task (articulatory suppression), supporting the view that a spatial WM component was implied in map memorization. In the second study, a correlational approach showed a significant correlation between the visual pattern test, a task assumed to test visual WM (Della Sala et al. 1999), and memory for landmark locations on a map. Taken together, the two studies support the idea that both spatial and visual components of WM sustain map learning. Similar results were found by Bosco et al. (2004), who also found significant correlations between the performance of spatial and visual WM tasks and a map memorization task.

Other studies indirectly suggested that mental rotation ability, as measured by the Mental Rotation Test (MRT) of Vandenberg and Kuse (1978), plays a role in the construction of a map-like representation derived from spatial language (Meneghetti et al. 2011), navigation (Fields and Sheldon 2006; Pazzaglia and De Beni 2001), and map presentation (Pazzaglia and De Beni 2006). However, all these studies focused on the construction of a map-like mental representation from different sources and perspectives. Does the MRT predict memory for maps? Our expectation was that MR ability is also implied in map learning: MRT requires maintenance and mental manipulation of abstract visual stimuli considered as a whole. Map memorization requires maintaining and mentally inspecting a visual configuration, a map, which is global in nature.

Maps also contain various verbal cues (e.g., names of landmarks and streets), which may help the recall and processing of spatial information. In this study, we tested the possible involvement of verbal ability in map learning by using a lexical competence task and examined its predictive value in comparison with that of verbal style.

Lastly, the Snowy Pictures Test (SPT) of Ekstrom et al. (1976), an imagery ability task, was used. Its administration allowed us to verify whether imagery is implied in map processing and to what extent imagery ability is connected with imagery style.

Aims and hypothesis

The aims of our study were to investigate the role played by cognitive styles and cognitive abilities in map learning. Regarding cognitive styles, we considered the impact of spatial, verbal, and object styles. Among cognitive abilities, we took into account mental rotation in the domain of spatial abilities, lexical competence in the domain of verbal abilities, and imagery. We aimed to verify: (1) the specific role played by mental rotation, lexical competence, and imagery ability in predicting the memorization of information contained in a map; (2) the relative predictive values of different cognitive styles (spatial, verbal, and object); (3) the portion of variance in map learning explained by cognitive styles, beyond that explained by cognitive (spatial, verbal, and imagery) abilities. To the best of our knowledge, this is the first time that MR, verbal and imagery ability, and cognitive styles have been related with map learning, considering not only the traditional verbalizer–visualizer dimension, but also the distinction between object and spatial visualizers. We expected to find that map learning would be related to MRT performance and that adopting a spatial cognitive style would facilitate map learning more than visual and verbal. In fact, although verbal style may be useful in memorizing the names of streets and landmarks, attention paid to the spatial features of a map allows the most important information regarding the location of landmarks and the global configuration of the map itself to be maintained. Second, considering the distinction between spatial and object visualizers, we expected that excessive attention to visual features (e.g., colors and shapes of landmarks) would distract learners' attention from important information (the locations of those landmarks) or overload their working memory capacity in an attempt to maintain both spatial and visual information. Lastly, we wished to assess the overall relationships between map learning, cognitive styles, and mental rotation ability. This aspect refers to a more general issue regarding the relationship between ability and cognitive style and will shed light on whether cognitive style and ability have independent effects on performance. We also aimed to verify whether the role of cognitive style would be different according to the level of MR ability. In other words, another aim of the study was to verify whether any positive effect of spatial cognitive style on map learning would emerge in any case or only when high MR ability was available.

Method

Participants

One hundred and seven high school students (50 women) voluntarily participated. Their mean age was 17.47 years, SD = 0. 65.

Materials

We measured cognitive style, imagery ability, spatial and verbal abilities, and map learning.

Cognitive style

To assess cognitive style, we used the Verbalizer–Visualizer Questionnaire (VVQ) (Richardson 1977) and the Object-Spatial Imagery Questionnaire (OSIQ) (Blajenkova et al. 2006). The VVQ is composed of 15 items focusing on the distinction between visualizer style (example item: 'I often use mental pictures to solve problems') and verbalizer style (example item: 'I like to learn new words'). Respondents were asked to indicate whether each item was true or false for them. One score was assigned for each item when the response matched the verbalizer style, so that a high total score (the sum of each item) indicated high verbal style.

The OSIQ is a 30-item self-report instrument consisting of two scales, each composed of 15 items, assessing, respectively, object visualization style (example item: 'My images are very vivid and photographic') and spatial visualization style (example item: 'I can easily imagine and mentally rotate three-dimensional geometric figures'). Participants were asked to read all the questionnaire items and rate each of them on a 5-point scale, with 1 = totally disagree and 5 = totally agree, and ratings 2–4 indicating intermediate degrees of agreement or disagreement. Six items were negatively formulated and were thus reverse-scored. The total score corresponded to the mean of the item scores.

Imagery ability

To assess imagery ability, we used the Snowy Pictures Test (SPT) (Ekstrom et al. 1976), which requires participants to recognize which objects are inserted in a set of 24 hard-to-see pictures. Participants were asked to write the corresponding object's name under each picture. The total score was the sum of items correctly recognized.

Mental rotation ability

Mental rotation ability was measured by the Mental Rotation Test (MRT) of Vandenberg and Kuse (1978), which assesses the ability to rotate abstract visual configurations mentally; 20 target objects made up of assembled cubes were presented, followed by four similar objects differing in degree of rotation or as mirror images. Instructions required identification of the two figures which were identical to the target but rotated in three-dimensional space. Each item was scored 1 when both correct alternatives were chosen, and individual item scores were summed in a total score.

Verbal ability

We used the verbal sub-test of the Primary Mental Ability Test (PMA) (Thurstone and Thurstone 1941) to assess verbal ability. The test consists of 48 items presenting one word and five potential synonyms. Respondents were asked to choose the correct one. The total score was the sum of correct responses.

Map learning

We chose two maps to assess map learning. The first was a map of the Italian city of Assisi, presenting a three-quarters view of the town, with quasi-topographical characteristics. All labels are in the language spoken by participants, and the main buildings are displayed vertically, together with trees, hills, etc. The map is rich in color and visual features. The second map was that of Prague, in the Czech Republic. It is a conventional bird's eye representation, with labels in a foreign language; only a few buildings are displayed, and the use of color and visual features is reduced (see Fig. 1).

The maps were scored by number of landmarks recalled, number of landmarks correctly positioned, number of streets recalled, number of streets correctly positioned, number of visual details recalled, and number of visual details correctly positioned. For both maps, the number of landmarks recalled was correlated with their correct positioning ($r = 0.89$ and $r = 0.93$, $p < .001$, respectively, for Assisi and Prague). The same positive relationships were found for street recall and correct positioning, but not for visual detail recall or positioning (ns for Assisi map and $r = 0.024$, $p = .01$ for Prague). Hence, the final score was computed by adding together the number of correctly positioned landmarks and streets, for each of the two maps. For instance, for the Assisi map, the first participants recalled 15 landmarks and correctly positioned 12; seven street names, all correctly positioned; and seven visual details, six correctly positioned. Their final score was 19 (12 + 7 correctly positioned landmarks and streets). In sum, this scoring took into account correctly recalled and positioned items, except visual ones. Twenty maps were scored by two independent judges. The correlations between their scores were above 0.80 for both landmarks and streets. One of the two judges completed the score, which ranged from 0 to 20 for the Assisi map and from 0 to 18 for the Prague map.

Procedure

All tests and questionnaires were administered in the informatics class of the school during group sessions of up to 15 participants each. The informatics class was mandatory, thus guaranteeing that all students had similar levels of knowledge of computer use. The maps were presented on a computer screen and all the other instruments on paper, following the same order for all participants: OSIQ, VVQ, first map learning and test, second map learning and test, SPT, MRT, and PMA.

First, participants were asked to fill in the OSIQ and the VVQ questionnaires with no time limit. Then they were asked to study each map for 5 min and to memorize all information. Participants studied one of the two maps and immediately afterward were asked to draw it from memory. The same procedure was repeated for the second map. Map order was balanced among participants. Participants were allowed for 6 min to perform the SPT, 8 min for the MRT, and four for the PMA. Due to organizational problems, the PMA was administered to 55 participants out of 107. Lastly, participants were asked to describe on a 3-point scale to what extent they were familiar with the cities of Assisi and Prague: 1 = not at all, 2 = slightly, and 3 = familiar. At the end, the aims of the research were explained to them, and they were thanked for participating.

A

B

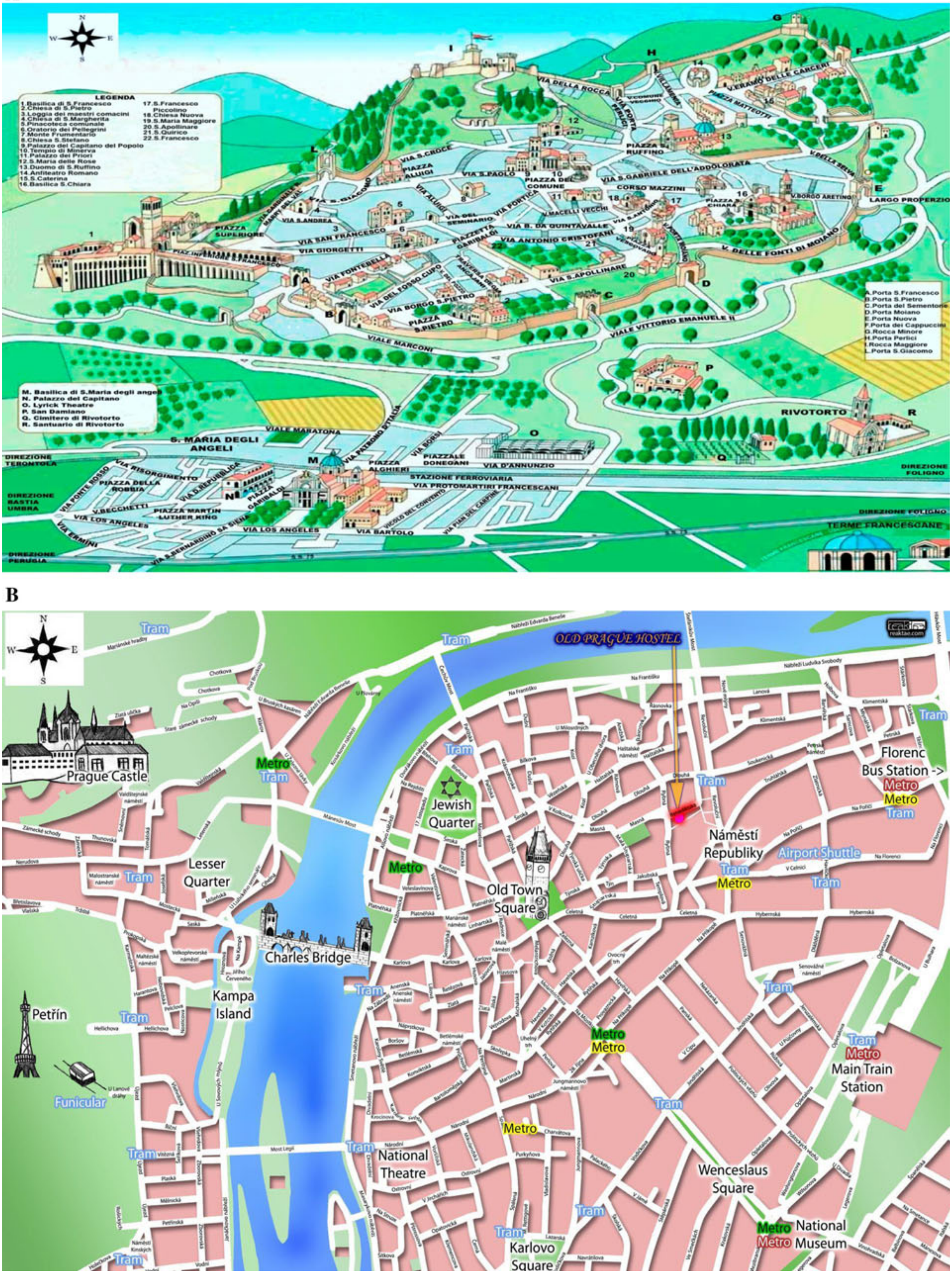

Fig. 1 Maps of Assisi (a) and Prague (b) used in study

Results

Psychometric properties of OSIQ

Principal components analysis with Varimax rotation and factor structure limited to two was carried out on the OSIQ items. It revealed a predominantly spatial factor (explained variance 17.02 %) and a predominantly object factor (explained variance 13.58 %). Table 1 lists details of factor loadings.

The internal reliability of the two scales was very similar to that reported in Blajenkova et al. (2006): for the spatial scale, Cronbach's $\alpha = 0.80$ (0.79 in that study) and 0.72 (instead of 0.83) for the object scale. The two α values were obtained after eliminating two items from each scale, i.e., items 14 and 20 for the spatial scale, and 15 and 30 for the object one. Otherwise, the α values would have been slightly lower. For each participant, the resulting 13 items from each factor were averaged to create object and spatial scale scores. As expected, the two scales were negatively correlated and the spatial scale had a significant correlation with the MRT (see Table 2). We also expected a correlation between the object scale and the SPT, but it turned out not to be significant. Thus, we confirmed that the Italian version of the OSIQ has an object and a spatial scale, both of which are reliable and that a relationship exists between the spatial scale and the MRT.

Table 1 Factor loadings of Italian translation of Object-Spatial Imagery Questionnaire (OSIQ)

Item	Factor	
	Spatial	Object
1	0.72	−0.12
2	0.59	0.01
3	0.76	−0.07
4	−0.27	0.46
5	0.50	−0.09
6	0.30	−0.28
7	0.01	0.35
8	0.12	0.43
9	0.76	0.21
10	0.01	0.14
11	0.19	−0.16
12	−0.08	0.63
13	0.52	0.42
14	0.13	0.21
15	−0.54	0.20
16	−0.06	0.54
17	−0.06	0.37
18	0.63	0.30
19	−0.16	0.57
20	−0.10	−0.32
21	−0.36	0.22
22	0.02	0.50
23	0.42	0.13
24	0.29	−0.29
25	0.17	0.66
26	−0.13	0.49
27	0.44	−0.02
28	−0.18	0.45
29	0.72	0.21
30	0.10	0.18

Gender differences

Although analysis of gender differences was not within the scope of our research, we examined their occurrence, as past research has shown male superiority in MRT (Voyer et al. 1995) and spatial visualization style, and female superiority in object visualization style (Blajenkova et al. 2006), while no gender difference has been observed for verbal scores (Blajenkova and Kozhevnikov 2009). Our results showed that men ($M = 8.39$, SD = 4.47) scored higher than women ($M = 6.14$, SD = 4.27) in the MRT, t (105) = 2.65, $p = .009$, confidence intervals 7.80–8.98 and 5.54–6.74, respectively, for men and women, and in the OSIQ spatial scale [men $M = 3.06$, SD = 0.55, women $M = 2.54$, SD = 0.48, t (105) = 4.89, $p < .001$, confidence intervals 2.99–3.13 and 2.43–2.57].

Correlation analysis

We first verified that familiarity with Assisi and Prague had no relationship with the map drawing task. The mean scores of familiarity of the two maps were, respectively, 1.19 (SD = 0.39, nobody rated '3') and 1.24 (SD = 0.47; only two participants rated '3') for the two cities. The mean scores did not differ, $p = .31$, and were low enough to exclude the possibility that previous knowledge could have affected subsequent recall. They showed very low correlations with the map drawing scores ($r = -0.02$ and $r = 0.06$ for Assisi and Prague, respectively, $p > .50$). We then calculated Pearson correlations among all the other variables considered (see Table 2).

Verbal abilities assessed with the PMA related with the verbal style ($r = 0.27$, $p < .05$), both being based, as expected, on verbal processes and, unexpectedly, with the SPT ($r = 0.28$, $p < .05$). This latter relationship may partly depend on the request for fast lexical retrieval shared by the two tests. The object and spatial subscales of the OSIQ were negatively related ($r = -0.23$, $p < .05$), as confirmed by other past studies. No other relationships among the individual differences measures were observed.

The relationships with map learning were different for the two maps. As expected, both correlated with the MRT.

Table 2 Mean (*M*) and standard deviation (SD) and correlations among study variables ($n = 107$; PMA: $n = 55$)

	M	SD	1.	2.	3.	4.	5.	6.	7.	8.
1. Map learning Assisi	7.25	4.24								
2. Map learning Prague	7.02	3.78	0.44**	–						
3. Imagery ability: SPT	9.56	3.08	0.02	0.01	–					
4. Mental rotation ability: MRT	7.34	4.50	0.32**	0.36**	0.06	–				
5. Verbal ability: PMA	25.62	6.52	−0.02	−0.18	0.28*	0.20	–			
6. Spatial visualization style: OSIQ	2.77	0.58	0.21*	−0.06	0.01	0.39**	0.13	–		
7. Object visualization style: OSIQ	3.30	0.44	0.02	−0.01	0.10	−0.19*	0.11	−0.23*	–	
8. Visualizer–verbalizer style: VVQ	4.88	2.52	0.02	0.24*	−0.02	0.14	0.27*	−0.01	−0.16	–

PMA Primary Mental Ability Test, *MRT* Mental Rotation Test, *SPT* Snowy Pictures Test, *VVQ* Verbalizer-Visualizer Questionnaire, *OSIQ* Object-Spatial Imagery Questionnaire

* $p < .05$; ** $p < .01$

However, the Assisi map was related to the OSIQ spatial scale but the Prague map was not. Instead, the Prague map was correlated with the VVQ, suggesting a positive relationship between verbal style and its memorization.

Relationships among variables

Two hierarchical multiple regression analyses blockwise method were run with MRT, styles, and the interactions as predictors and map learning as dependent variables. In step 1, the following were inserted as independent variables: the MRT, which correlated with memory performance of both maps; the Prague scores, in the analysis conducted on the Assisi map; and the Assisi scores in the analysis conducted on the Prague map. In step 2, the three styles were added: verbal, OSIQ spatial, and OSIQ object. Lastly, in step 3, the interaction spatial (or verbal) style × mental rotation ability was considered. Results showed that, for the Assisi map, mental rotation ability and Prague scores altogether explained 20 % of the variance and that their effects were significant. Spatial style added another 2 % (22 % of variance explained in total; all $F\text{s} > 5.95$, $p\text{s} < .001$). The effect of the interaction was not significant (see Table 3).

For the Prague map, mental rotation ability and Assisi scores explained altogether 23 % of variance. Spatial and verbal styles added 8 % and the interaction verbal style x mental rotation ability 2 % more (33 % of variance explained in total; all $F\text{s} > 9.80$, $p\text{s} < .001$). The effects of OSIQ Spatial, VVQ, and interaction were significant. It should be noted that OSIQ spatial was negatively correlated with the memory performance of the Prague map.

These results support the idea that MR ability is required in map processing, independently of map characteristics. Cognitive styles also have an influence, beyond that of the MRT, but their effects are dependent on the characteristics of the map.

Discussion

The role played by mental rotation ability and cognitive style in map learning was explored by examining two different maps and three styles: object visualizers, spatial visualizers, and verbalizers.

A relationship between mental rotation ability and map learning was found for both maps. This indicates that the ability to maintain and manipulate visual stimuli mentally is crucial in map processing. As we used the MRT as the only test to assess spatial ability, we did not know whether the relationship we found was specific for mental rotation ability or whether it could be extended to other spatial factors, such as spatial visualization and spatial perception (Linn and Petersen 1985). Further investigation is needed. However, in the light of the present outcome, we may assume that map processing and mental rotation share the ability to maintain and sometimes transform a visual configuration as a Gestalt.

Effects due to cognitive styles differed between the two maps. This was a quite unexpected result, which suggests new reflections and opens space to further investigation. An important suggestion is that styles interact with the characteristics of the material to be memorized, to the point that the same variable (spatial style) has positive effects on the processing of one map and negative on the other. For the Assisi map, with a higher proportion of visuo-spatial features, spatial style was related with map learning. For the Prague map, with fewer visuo-spatial features and labels in an unknown foreign language, spatial style has a detrimental effect, whereas verbal style appeared to play a supporting role. These results confirm and extend those obtained in previous research, showing that mental rotation ability is implicated in map learning and predicts elements (such as landmarks and streets) correctly located in a map drawing task. Further, they suggest that not all maps are the same. Although the element they have in common is the

Table 3 Multiple regression analyses predicting map learning

Predictors	β	t	p	R^2
Assisi map				
Step 1				
Prague map learning	0.37	3.96	<0.001	0.20
Mental rotation ability	0.19	2.00	0.048	
Step 2				
Prague map learning	0.43	4.47	<0.001	0.22
Mental rotation ability	0.10	0.99	ns	
Spatial style	0.20	2.07	0.041	
Object style	0.03	0.34	ns	
Verbal style	−0.09	−1.00	ns	
Step 3				
Prague map learning	0.42	4.38	<0.001	0.22
Mental rotation ability	0.11	1.04	ns	
Spatial style	0.20	2.08	0.040	
Object style	0.04	0.43	ns	
Verbal style	−0.08	−0.88	ns	
Spatial style × mental rotation ability	−0.06	−0.63	ns	
Prague map				
Step 1				
Assisi map learning	0.36	3.96	<0.001	0.23
Mental rotation ability	0.25	2.78	0.007	
Step 2				
Assisi map learning	0.38	4.47	<0.001	0.31
Mental rotation ability	0.32	3.47	0.001	
Spatial style	−0.25	−2.79	0.006	
Object style	0.04	0.48	ns	
Verbal style	0.19	2.30	0.024	
Step 3				
Assisi map learning	0.39	4.62	<0.001	0.33
Mental rotation ability	0.30	3.24	0.002	
Spatial style	−0.26	−2.94	0.004	
Object style	0.06	0.75	ns	
Verbal style	0.18	2.23	0.028	
Verbal style × mental rotation ability	0.17	2.10	0.038	

implication of the MRT, maps rich in visual properties may require spatial cognitive style, with reference to the distinction, within the visualizer style, between object and spatial visualizers; maps with more verbal cues are recalled better by people who use verbal cognitive style. Future research may further investigate this point by providing more controlled materials, e.g., maps with the same levels of visuo-spatial information and verbal labels, either in native or foreign languages or with labels in the same language but different visuo-spatial contents.

The maps we used differed in both the quantity of visual information provided and perspective. These dimensions were not systematically varied. We used two existing maps. Although this increased ecological validity, it was a limitation of the study and made interpretation of the differences found in their memorization more speculative. Future investigations using more controlled materials will further qualify these differences.

Interestingly, we did not find a negative correlation between object visualization style and number of elements recalled. This means that a tendency to encode and process visual information does not in itself impede memorization of important information (locations of constituent units such as landmarks and streets). Even so, it is the predisposition to encode and process visual information schematically which leads to good memorization. This attitude, together with mental rotation ability, ensures good performance, at least for a certain type of map

More generally, our findings support the object spatial characterization proposed by Blajenkova et al. (2006) and confirm the existence of this further distinction within visual style. In addition, the importance of the construct of cognitive style, explaining mind functioning and its partial independence with ability, is confirmed here. It is worth noting that cognitive styles behave in a flexible way, and their usefulness depends on the material to be processed. From an educational point of view, these results emphasize the importance of promoting a flexible attitude. Making people aware of their preferential style and instructing them to shift strategically to alternative styles when task requests recommend it matches more recent theorizations of cognitive style and avoids the possibility of considering styles as a sort of unmodifiable personality trait. Suggestions in education are not to adapt materials and teaching to individual cognitive styles (see Pasher et al. 2008, for a critical position to this approach) but, rather, to promote flexibility and metacognitive control (Kozhevnikov 2007). What suggestions may be provided to help people in path finding or orienting tasks? It is advisable to foster mainly the development of mental rotation ability and then the adoption of the most suitable style. If maps report mainly verbal labels, then recalling them and their correct position would be the better strategy; conversely, if maps are rich in visuo-spatial features, then using a spatial style supported by proper mental rotation ability is the recommended strategy. Testing ways of helping people to achieve greater and more correct recall of maps is a promising avenue for future research.

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