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Gender differences in spatial orientation: A review

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Abstract

While significant gender differences in spatial abilities consistently emerge, results concerning gender differences in spatial orientation skills are mixed, ranging from "marked differences" to "no-differences". In order to improve our understanding of this phenomenon, literature about gender differences in spatial orientation skills is reviewed from 1983 to 2003. The influence of biological and socio/cultural factors is discussed as well as the hypothesis that gender differences are due to different strategies used to solve orientation tasks. The role of personality factors and the influence of spatial anxiety in orientation performance are also discussed. An additional interpretative hypothesis is proposed highlighting the role of task-difficulty expressed in terms of Visuo-Spatial Working Memory involvement. This interpretation can explain the overall results, resolving some apparent contradictions.

1. Introduction

The aim of the present review is to provide hints for future research on gender differences in spatial orientation. We do not try to explain the causes of gender differences. We just try to explain the large variability of the results that emerged in the previous literature on gender differences in spatial orientation.

Two distinct concepts are often confounded: spatial ability and spatial orientation.

Spatial ability generally refers to the ability to generate, represent, transform, and recall spatial information (Linn & Petersen, 1985). Gender differences in spatial abilities are considered among the largest gender differences in all cognitive abilities (Lawton & Morrin, 1999). In traditional tests of basic spatial abilities, males perform better than females; however, the size of this effect changes depending on the type of the spatial ability measured (Halpern, 1992). Many results show that males perform better in some spatial tasks, especially in the Mental Rotation Task (Sanders, Soares, & D'Aquila, 1982; Harshman, Hampson, & Berenbaum, 1983; Linn & Petersen, 1985). The evidence is much less clear with respect to performance on more ecologically valid tasks (Montello, Lovelace, Golledge, & Self, 1999). On measures concerning spatial orientation (which is the complex of all the skills used for locating themselves with respect to a point of reference or an absolute system of coordinates) mixed results have been indeed obtained (Lawton & Morrin, 1999).

Therefore, it is important to keep in mind the distinction between spatial ability and orientation skills. Considering them as similar capacities can be misleading. There are some studies reporting a nonsignificant relationship between orientation tasks and spatial abilities (Lorenz & Neisser, 1986; Allen, Kirasic, Dobson, Long, & Beck, 1996). Orientation skills and spatial abilities have different characteristics. For instance, orientation skills always involve an environment and imply a movement (actual navigation or imagined map scanning) and the acquisition of information about the surroundings. When considering gender differences in orientation conflicting results often emerge, ranging from studies showing that males outperform females (Galea & Kimura, 1993; Schmitz, 1997; Malinowski & Gillespie, 2001; Waller, Knapp, & Hunt, 2001) to studies in which gender differences are totally absent (Sadalla & Montello, 1989; Taylor & Tversky, 1992a; Brown, Lahar, & Mosley, 1998). Currently, it is

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not possible to assert the existence of gender differences in spatial orientation. At the same time we must remember that spatial orientation is a complex process that depends on numerous basic cognitive functions. For these reasons, studies investigating spatial orientation use a wide variety of measures. In fact, different tasks have been adopted (landmark and/or route recall, landmark replacement, pointing, map drawing, straight-line and route distance estimation, verbal description of a route, route learning, route reversal, wayfinding, orienteering, maze learning) and different environments (maps, real outdoor environments, real indoor environments, virtual tours) and self-report questionnaires. This multiplicity of measures and environmental contexts contributed to produce different patterns of results and has generated some difficulties in reaching a satisfactory interpretation of the findings.

The aim of this work is not only to analyse the literature concerning gender differences in spatial orientation, but also to look for an interpretative hypothesis able to explain the phenomenon of the presence/absence of such differences.

With the aim of achieving a complete picture of the results so far obtained on gender differences in spatial orientation, we reviewed all the experimental studies (from 1983 to 2003) comparing male and female performance on spatial orientation tasks. For each study we report a short description of the tasks used. The measured dependent variables, the results concerning gender differences and the environment to which the tasks refer are also reported in the following table.

A simple inspection of Table 1 shows variations in performance on orientation tasks. If the self-report questionnaires are excluded (because they do not give us any information on performance), a male advantage in about half the cases (49.28%) is observed. At the same time, a consistent percentage of cases (40.58%), in which gender differences do not appear, emerges. It should be noted that a female superiority very seldom emerges.

In the attempt to find a factor able to explain the results concerning the presence or the absence of gender differences, we grouped each study, first on the basis of the environmental context and then on the basis of orientation task type.

It is possible to think, for instance, that males perform better than females in configurational tasks (pointing, distance estimation) because of their preference for Euclidean strategies (Lawton, 1994). Otherwise, a factor related to the presence/absence of gender differences could be identified in the environmental context. For instance, studies with ecological approaches usually do not show marked gender differences (Halpern, 1992; Galea & Kimura, 1993; Rossano & Moak, 1998). On this basis, we could suppose that, in a symbolic no-ecological environment (e.g. maps), males might perform better than females, whereas in a real environment their performance could be even.

The different sources of environmental learning can be categorized as follows:

Real environment: Spatial orientation in real environments was studied in a wood (Malinowski & Gillespie, 2001), in a building (Sadalla & Montello, 1989; Lawton, 1996; Lawton, Charleston, & Zieles, 1996), in a maze (Schmitz, 1997), and in a university campus (Kirasic, Allen, & Siegel, 1984; Montello & Pick, 1993; Saucier et al., 2002). In 58.82% of the conditions in which exploration took place in a real environment, males perform better than females. Yet there is a consistent percentage of cases (41.18%) in which gender differences do not emerge. Females never perform better than males.

Simulated environment: Some examples of spatial orientation in simulated environment are 3-D computer simulations (Moffat, Hampson, & Hatzipantelis, 1998; Lawton & Morrin, 1999; Sandstrom, Kaufman, & Huettel, 1998; Waller et al., 2001), video recording (O'Laughlin & Brubaker, 1998) and slide sequences (Holding & Holding, 1989). Here again, in a high percentage (57.14%) males perform better than females, but in the 42.86% of the cases differences between males and females do not emerge. Again, females never perform better than males. Within simulated environments, it is possible to distinguish between situations that allow interaction with the environment (3-D computer simulations) and others that do not (slides and video recordings). In the first one, participants can move themselves and actively decide where to go. In the second one, they are passively shown a static (slides sequence) or dynamic (video recordings) environment. In the ''active situation'' the number of cases in which males outperform females is 85.71%; in the remainder cases performance is even. When the ''passive situation'' is considered, males perform better than females in a lower percentage of cases (28.57%). There are no differences in 71.43% of the cases. This effect could be given by a higher familiarity of the males with the 3-D computer simulations, as they spend more time playing videogames (Barnett et al., 1997). It could be also reasonable to hypothesize that the active interaction with the environment increases the complexity of the task, as more elements have to be considered and elaborated. Such hypothesis will be exhaustively illustrated later.

Map: When the environment is represented by a map, (McGuinness & Sparks, 1983; Miller & Santoni, 1986; Ward, Newcombe, & Overton, 1986; O'Laughlin & Brubaker, 1998; Galea & Kimura, 1993; Dabbs, Chang, & Strong, 1998; Brown et al., 1998; Coluccia & Martello, 2004) the percentage of cases in which males perform better than females (42.11%) is only slightly superior to the number of cases (39.47%) in which

Table 1
List of the experimental studies dealing with gender differences in spatial orientation skills (1983–2003)

Authors	Tasks	Dependent variables	Gend. diff.	Contexts
McGuinness and Sparks (1983)	Sketch map	Number of missing buildings	F = M	Map
McGuinness and Sparks (1983)	Sketch map	Extra items included (details)	F > M	Map
McGuinness and Sparks (1983)	Sketch map	Major roads and paths included (absolute number)	M > F	Map
McGuinness and Sparks (1983)	Sketch map	Spatial coordinate errors (absolute number)	M < F	Map
McGuinness and Sparks (1983)	Sketch map	Relative deviation error	F < M	Map
Kirasic et al. (1984)	Pointing to difficult landmarks	Mean error	M < F	Real (campus)
Kirasic et al. (1984)	Pointing to easy landmarks	Mean error	F = M	Real (campus)
Ward et al. (1986)	Verbal description of a route (map present)	Number of errors and omissions	F = M	Map
Ward et al. (1986)	Verbal description of a route (map absent)	Number of errors and omissions	M < F	Map
Ward et al. (1986)	Verbal description of a route	Number of cardinal and mileage terms	M > F	Map
Miller and Santoni (1986)	Verbal description of a route	Number of Euclidean terms	M > F	Map
Miller and Santoni (1986)	Verbal description of a route	Number of landmark terms	F > M	Map
Sadalla and Montello (1989)	Pointing to familiar landmarks	Mean error	F = M	Real (building)
Holding and Holding (1989)	Landmark relocation	Mean error	F = M	Slide sequence
Holding and Holding (1989)	Pointing	Mean error	M < F	Slide sequence
Holding and Holding (1989)	Pointing	Response time	F = M	Slide sequence
Holding and Holding (1989)	Route distance estimation	Mean error	M < F	Slide sequence
Holding and Holding (1989)	Straight-line distance estimation	Mean error	F = M	Slide sequence
Taylor and Tversky (1992a, b)	Sketch map	Number of omitted elements	F = M	Verbal description, map
Taylor and Tversky (1992a, b)	Sketch map	Number of incorrect positioning	F = M	Verbal description, map
Montello and Pick (1993)	Pointing with familiar landmarks	Mean error	F = M	Real (campus)
Galea and Kimura (1993)	"Euclidean composite"	Euclidean task's composite score	M > F	Map
Galea and Kimura (1993)	"Landmark composite"	Landmark task's composite score	F > M	Map
Galea and Kimura (1993)	Map learning	Number of errors	M < F	Map
Galea and Kimura (1993)	Map learning	Number of trials	M < F	Map
Galea and Kimura (1993)	Map learning	Time to complete all trials	M < F	Map
Galea and Kimura (1993)	Direction questions	Number of correct answers	M > F	Map
Galea and Kimura (1993)	Map-extrapolation test	Number of correct answers	F = M	Map
Galea and Kimura (1993)	Landmark recall	Number of correct recall	F > M	Map
Galea and Kimura (1993)	Street names recall	Number of correct recall	F > M	Map
Galea and Kimura (1993)	Straight-line distance estimation	Number of correct answers	F = M	Map
Lawton (1994)	Self-report questionnaire	Spatial anxiety	M < F	
Lawton (1994)	Self-report questionnaire	Route strategies	F > M	
Lawton (1994)	Self-report questionnaire	Orientation strategies	M > F	
Devlin and Bernstein (1995)	Wayfinding	Number of wrong directions	M < F	Simulated
Lawton et al. (1996)	Route reversal task	Number of shortcut/exact retrace	F = M	Real (building)
Lawton et al. (1996)	Pointing	Mean error	M < F	Real (building)
Lawton et al. (1996)	Self-report questionnaire	Task uncertainty	M < F	
Lawton et al. (1996)	Route reversal task	Time taken	F = M	Real (building)
Lawton (1996)	Pointing self-evaluation	Self-confidence degree	M > F	
Lawton (1996)	Pointing	Mean error	M < F	Real (building)
Lawton (1996)	Pointing	Time response	M < F	Real (building)
Lawton (1996)	Self-report questionnaire	Spatial anxiety degree	M < F	

Table 1 (*continued*)

Authors	Tasks	Dependent variables	Gend. diff.	Contexts
Lawton (1996)	Self-report questionnaire	Route strategies	F > M	
Lawton (1996)	Self-report questionnaire	Orientation strategies	M > F	
Schmitz (1997)	Verbal description of a route	Number of directional terms	M > F	Real (maze)
Schmitz (1997)	Maze performing	Mean velocity	M > F	Real (maze)
Schmitz (1997)	Self-report questionnaire	Spatial anxiety	M < F	
Sandstrom et al. (1998)	Reaching a hidden target, using geometrical cues	Time taken	M < F	Simulated (water maze)
Sandstrom et al. (1998)	Reaching a hidden target, using landmark cues	Time taken	F = M	Simulated (water maze)
O'Laughlin and Brubaker (1998)	Sketch map	Number of included elements	F = M	Simulated (film)
O'Laughlin and Brubaker (1998)	Sketch map	Number of correct positioning	F = M	Simulated (film)
O'Laughlin and Brubaker (1998)	Self-report questionnaire	Route strategies	F > M	
O'Laughlin and Brubaker (1998)	Self-report questionnaire	Orientation strategies	M > F	
Moffat et al. (1998)	Wayfinding	Time taken to find the exit	M < F	Simulated (3D maze)
Moffat et al. (1998)	Wayfinding	Number of wrong turns	M < F	Simulated (3D maze)
Dabbs et al. (1998)	Verbal description of a route	Number of Euclidean and cardinal terms	M > F	Map
Dabbs et al. (1998)	Verbal description of a route	Number of landmark terms	F > M	Map
Brown et al. (1998)	Map learning	Time taken	F = M	Map
Brown et al. (1998)	Verbal description of a route	Number of included elements	F = M	Map
Lawton and Morrin (1999)	Pointing	Mean error	M < F	Simulated
Pazzaglia et al. (2000)	Self-report questionnaire	Route representations	F = M	
Pazzaglia et al. (2000)	Self-report questionnaire	Survey representations	M > F	
Pazzaglia et al. (2000)	Self-report questionnaire	Orientation ability	M > F	
Waller et al. (2001)	Pointing	Mean error	M < F	Simulated (3D)
Malinowski and Gillespie (2001)	Orienteering	Time taken	M < F	Real (wood)
Malinowski and Gillespie (2001)	Orienteering	Number of points found	M > F	Real (wood)
Saucier et al. (2002)	Wayfinding with "Euclidean instructions"	Time taken	M < F	Real (campus)
Saucier et al. (2002)	Wayfinding with "Euclidean instructions"	Number of wrong directions	M < F	Real (campus)
Saucier et al. (2002)	Wayfinding with "landmark instructions"	Time taken	F = M	Real (campus)
Saucier et al. (2002)	Wayfinding with "landmark instructions"	Number of wrong directions	F = M	Real (campus)
Coluccia and Martello (2004)	Map placement (irregular map)	Number of correct answers	F = M	Map
Coluccia and Martello (2004)	Map placement (regular map)	Number of correct answers	M > F	Map
Coluccia and Martello (2004)	Orientation specification test (irregular map)	Number of correct answers	F = M	Map
Coluccia and Martello (2004)	Orientation specification test (regular map)	Number of correct answers	M > F	Map
Coluccia and Martello (2004)	Route distance estimation (irregular map)	Number of correct answers	F = M	Map
Coluccia and Martello (2004)	Route distance estimation (regular map)	Number of correct answers	M > F	Map
Coluccia and Martello (2004)	Route Recognition (irregular map)	Number of correct answers	F = M	Map
Coluccia and Martello (2004)	Route Recognition (regular map)	Number of correct answers	M > F	Map
Coluccia and Martello (2004)	Straight-line distance estimation (irregular map)	Number of correct answers	F = M	Map
Coluccia and Martello (2004)	Straight-line distance estimation (regular map)	Number of correct answers	F = M	Map
Coluccia and Martello (2004)	Wayfinding (irregular map)	Number of correct answers	F = M	Map
Coluccia and Martello (2004)	Wayfinding (regular map)	Number of correct answers	M > F	Map

Table 2
Grouping on the basis of context

	M > F	% M > F	M = F	% M = F	M < F	% M < F	*N* total
Simulated environment	8	57.14	6	42.86	0	0	14
Real environment	10	58.82	7	41.18	0	0	17
Map	16	42.11	15	39.47	7	18.42	38

Number of cases and relative percentages.

Table 3
Grouping on the basis of the orientation task

	M > F	% M > F	M = F	% M = F	M < F	% M < F	*N* total
Pointing	9	64.29	5	35.71	0	0	14
Wayfinding	11	61.11	7	38.89	0	0	18
Map drawing	2	22.22	5	55.56	2	22.22	9
Distance estimation	2	28.57	5	71.43	0	0	7

Number of cases and relative percentages.

gender differences do not emerge. In 18.42% of the cases females perform better than males.

In Table 2 we report results concerning gender differences as a function of the type of environmental context in which the task is carried out.

From the data summarized in Table 2, a significant relationship between the type of environmental context and the presence/absence of gender differences does not emerge (chi-square = 3.96, $p = .86$). The pattern of results reveals a trend, favouring males. Such trend, however, is accompanied by a consistent percentage of cases in which differences between males and females are not present.

However, it is worthwhile noting that the percentage of cases favouring males is higher in Virtual and real environments than in maps. This could be related to the route perspective that both offer. In the maps—the only ones to offer a survey perspective—we find the lowest percentage of cases in which males outperform females. There are even some cases in which females perform better than males. It is possible that females take more advantage than males from a situation in which the survey perspective, which is more complete than the route one, is already offered. Females might not easily form the survey representation but, when the survey perspective is already offered, gender differences are levelled off. In line with this hypothesis, Montello et al. (1999) found that males outperform females on tests of spatial knowledge of places from direct experience rather than tests of map-derived knowledge.

In real and virtual environments, we can assume that males are successful in switching from a route perspective to a survey one, whereas females are more constrained by the kind of given perspective (Sandstrom et al., 1998).

Now we will proceed to consider how the kind of task used to measure spatial orientation abilities affects males and females performance.

As shown in Table 3, most frequently used tasks can be grouped as follows:

Pointing tasks (Kirasic et al., 1984; Sadalla & Montello, 1989; Holding & Holding, 1989; Galea & Kimura, 1993; Montello & Pick, 1993; Lawton, 1996; Lawton et al., 1996; Lawton & Morrin, 1999; Waller et al., 2001). In this category, it emerges that, in 64.29% of the cases, males perform better than females, both in time taken to solve the task and in response accuracy. However, there are some cases (35.71%) in which the performance of the two genders is similar. Then it is evident that female performance is never better than the male's. So we could assert that in pointing task, males are generally more able than females; but situations with males performing equal to females are also present. As the pointing task could differ in several ways, some additional categorizations are added. Some pointing tasks were performed in a paper and pencil version (Kirasic et al., 1984; Holding & Holding, 1989; Galea & Kimura, 1993; Lawton et al., 1996). Some other pointing tasks were performed using a circle-and-arrow device, for example, a circular piece of cardboard with a pointer attached to the centre of the circle. Such a device implies the use of motor components (Sadalla & Montello, 1989; Montello & Pick, 1993; Lawton, 1996; Lawton & Morrin, 1999; Waller et al., 2001) and it could differ from a paper and pencil version. In the "device version", in 67% of cases males outperform females and in 33% of cases the performance of the two genders is similar. Same identical distributions are found in the "paper and pencil version", suggesting that the way to perform the pointing task does not affect gender differences. A further difference in performing the pointing task could emerge between a situation in which the participants are asked to pointing from their own location (real test) and a situation in which the participant has to imagine being in a different place (simulated test). Differences between real and simulated test are exhaustively explained in Rossano and Moak (1998). In the ''real test pointing'', in most cases (67%) males outperform females, while gender differences do not emerge in 33% of cases. In the ''simulated test pointing'', in 62% of cases males outperform female, and in 38% of cases the performance is similar. Again, gender differences seem unaffected by the kind of pointing task.

Wayfinding: The performance in this task was measured in different ways: route learning (Schmitz, 1997; Saucier et al., 2002), arrival point-finding tasks (Devlin & Bernstein, 1995; Moffat et al., 1998; Sandstrom et al., 1998; Coluccia & Martello, 2004), route reversal (Lawton et al., 1996) and orienteering (Malinowski & Gillespie, 2001). In most cases (61.11%) males outperform females, while gender differences do not emerge in 38.89% of cases. In line with the pointing task, females never perform better than males.

Sketch map (McGuinness & Sparks, 1983; Taylor & Tversky, 1992b; O'Laughlin & Brubaker, 1998): This is the only task showing a percentage of cases (22.22%) in which females outperform males. It is interesting to note that in the sketch map tasks males are particularly aware of routes and connectors while females appear more sensitive to landmarks (McGuinness & Sparks, 1983). In fact, most of the 22% of cases where females outperform males concern tasks about landmarks and map elements. Moreover, in this task gender differences do not appear in more than half of the cases (55.56%), whilst only in 22.22% of cases males perform better than females.

Distance estimations (Holding & Holding, 1989; Galea & Kimura, 1993; Coluccia & Martello, 2004): Gender differences in this task are less marked than in all the other tasks considered so far. In fact, males outperform females only in the 28.57%, while in most cases, gender differences (71.43%) do not emerge. We can also note that the few cases in which males perform better than females are related to route distance estimation.

Grouping on the basis of the orientation task provides a rather intricate pattern: pointing, wayfinding and map drawing show a notable percentage of cases (respectively 64.29%, 61.11% and 54.55%) in which males outperform females and a considerable percentage of cases (respectively 35.71%, 38.89% and 27.27%) in which gender differences do not emerge. The map drawing task is the only task indicating that females (18.18% of cases) outperform males. This phenomenon could be related to the advantage that females have mentioned above when directly using a survey representation. In fact, every case in which females perform better than males occurs in a map study. Finally, the distance estimation task presents a peculiar trend, as in most cases (71.43%) there are no gender differences in performance. Particularly, gender differences never emerge in straight-line distance estimation.

Now we will analyse some other aspects reported by the literature; these aspects do not concern specifically the performance in orientation tasks but rather the kind of the strategies used and the self-evaluation of the orientation sense.

The strategies used in spatial orientation have been investigated in different situations; specifically:

Verbal description of a route (Miller & Santoni, 1986; Ward et al., 1986; Schmitz, 1997; Brown et al., 1998; Dabbs et al., 1998). These studies illustrate the different ways in which males and females give indications to reach a destination. In all the situations, males paid a greater attention to configurational aspects, using terms indicating cardinal points (i.e. ''you must go towards the North'') and distances (i.e. ''you must turn to the right after 300 meters'') in their verbal indications, Conversely, females showed to use more frequently terms indicating landmarks (i.e. ''you must turn to the right near the restaurant'').

Self-report questionnaires for strategies (Lawton, 1994, 1996; O'Laughlin & Brubaker, 1998; Pazzaglia, Cornoldi, & De Beni, 2000). Based on the given answers it emerges that males maintain a survey perspective when they imagine moving in the environment, preferentially relying on the visuo-spatial properties of the environment and on configurational, orientation strategies. On the other hand, females maintain a route perspective; rely on landmarks and on procedural ''route ''strategies involving route's knowledge.

Finally, with regard to self-evaluation questionnaires on orientation skills (Lawton, 1994, 1996; Lawton et al., 1996; Schmitz, 1997; Pazzaglia et al., 2000), a homogeneous pattern emerges in the results: males estimate themselves to be more able in orientation and they show greater confidence in their own ability than females. On the contrary, females report a higher level of spatial anxiety than males, related to the fear of getting lost.

Whilst the results concerning gender differences in the strategies used and in self-reported orientation skills are consistent within the examined literature, the pattern of results concerning gender differences in performance is not so constant. The variability between studies in fact does not seem to depend strictly either on the type of environment or on the type of task. Because of the unsatisfying explanations that emerge with the grouping method, another attempt will be carried out. In order to clarify the complex pattern of gender differences, all the interpretative theories about gender differences in spatial orientation will be briefly reviewed. We will discuss firstly generic spatial abilities theories (biological, environmental and interactionist theories), and secondly specific spatial orientation interpretations (Evolutionistic theories, strategies and personality approaches).

2. Interpretations of gender differences

2.1. Interpretations of gender differences in spatial abilities

2.1.1. Biological theories

Biological explanations were proposed which considered sex differences in rats in maze-learning tasks (Foreman, 1985; Margueles & Gallistel, 1988; Williams, Barnett, & Meck, 1990).

Biological hypotheses are based on the assumption that sexual hormones influence cognitive development. In fact, hormone manipulation affects not only sexual behaviour but also some aspects of cognition, in particular spatial memory (Williams et al., 1990).

Dawson, Cheung, and Lau (1975), for example, report that the administration of testosterone to female rats during the prenatal period, improves performance in maze learning. On the other hand, castration at birth of male rats impairs the accuracy to choose the right direction in a radial maze.

In addition several studies (Suzuki, Augerinos, & Black, 1980; Foreman, 1985; Margueles & Gallistel, 1988) showed that male rats, while running in a maze, usually ignore landmarks and show an orientation behaviour based on the "Euclidean properties" of the room containing the maze (e.g. the shape of the room or the metric relation between the long wall and the short wall of the room). Williams et al. (1990) found that male rats, when instructed to learn a maze, rely on geometrical or configurational cues. Such cues are also called extramaze cues and depend on the geometry of the room (e.g. the maze is enclosed in a room with circular or rectangular contours). Male rats performance is impaired if the geometry of the room changes, but it is unaffected if landmarks are modified. On the other hand, female rats performance is always poor in both landmark and room-geometry conditions and it is significantly lower than male rats performance.

However, it is not clear how much of the sex differences present in rats can be extended to humans. It seems likely that, among humans, biological effects interact with experiential factors.

Kimura and Hampson (1994) found that in some tasks of verbal fluency women improve their performances up to 10%, just during the periods of high concentration of oestrogen (about 5–10 days before menstruation). In spatial ability tests, however, women perform well when hormones levels are low (when menstrual cycle starts). Otherwise, male performance in spatial tasks seems to fluctuate in during the day, in accordance with natural variations of testosterone levels: when concentration of male hormones is high, performance increases; when concentration is low, performance decreases (Moffat & Hampson, 1996). Furthermore, it was found that administration of androgen to females could significantly reduce verbal ability and enhances spatial performance, whereas deprivation of androgen has the opposite effects on males (Van Goozen, Cohen–Kettenis, Gooren, Frijda, & Van De Poll, 1995). All together these results are consistent with the hypothesis of hormonal levels.

According to Annett (1992) a cerebral pattern strongly left-hemisphere-dominant for language has a negative influence on spatial ability development. Females, in particular, seem more disadvantaged than males in spatial ability, because they have an advantage in early development of the left-hemisphere for language. As a result of this early left hemisphere advantage, females spontaneously prefer verbal strategies for solving problems and they are more likely to be at risk for poor spatial ability. All the previously discussed results are in favour of the presence of some biological basis (hormonal levels and cerebral pattern) for sex differences. Nevertheless, there are environmental factors (society, culture, race, etc.) that can strongly modify the differences between males and females.

2.1.2. Environmental factors

Gaulin and Hoffman (1988) conclude in their review that gender differences in spatial abilities, allowing for a biological basis, are strongly modulated by experience and learning. A positive correlation between spatial performance and participation to high-spatial activities emerges in Baenninger and Newcombe's (1989) meta-analysis.

The different levels of spatial ability could be due to the different time spent in spatial activities by males and females. Usually males have more experience in activities that enhance the development of spatial skills (Lawton & Morrin, 1999). Males, in fact, since early childhood, play games with high spatial components, like exploratory games, team sports, LEGO-construction (Goldberg & Lewis, 1969; Baenninger & Newcombe, 1989) and videogames (Barnett et al., 1997), being exposed to a higher "spatial experience" than females. In addition, boys are allowed more frequently than girls to explore new environments (Webley, 1981).

2.1.3. Interactionist theories

The interactionist approach asserts that gender differences are caused by a continuous interaction between environmental factors (experienced-based) and biological factors (natural predispositions). According to Sherman's (1978) bent twig theory, the innate predisposition to particular abilities influences the choice of particular activities. Consequently males, naturally interested in spatial activities, actively search for high-spatial experiences and spend much more time in them than females. Such activities, in turn, enhance the development of spatial abilities, increasing the initial differences between males and females. Casey (1996b) hypothesizes that males innate predisposition for spatial abilities depends on their particular pattern of cerebral organization, characterized by low hemispheric lateralization. In fact, such cerebral organization seems to be more frequent in men (Annett, 1992). Consequently, individuals having this particular pattern and, at the same time, high exposition to spatial experience can excel in spatial abilities compared to individuals having the same spatial exposition but different cerebral patterns. Individuals with this particular pattern of cerebral organization and low exposition to spatial experience are not likely to develop their spatial abilities.

2.2. Interpretations of gender differences in spatial orientation

2.2.1. Evolutionistic theories

Following an evolutionistic approach, Silverman and Eals (1992) hypothesized that, during the course of time, women developed a highly specialized memory system for object location. Since prehistoric age, landmark positions have been more useful for females than males. Females spent long time in caverns taking care of their children, while males needed to know Euclidean and configurational properties of their hunting-area, exploring extended and unfamiliar environments in search of food.

2.2.2. Differences in strategies

This hypothesis is suggested by some differences between males and females regarding the strategies used in orientation tasks. Males seem to rely on global reference points and configurational or ‘‘survey strategies’’ (e.g. maintaining a sense of their own position in relation to compass directions, keeping in mind the position of the sun in the sky, cardinal points, town centre, starting point, etc.). Females, indeed, show use of landmarks and apply procedural or ‘‘route strategies’’, attending to instructions on how to get from place to place (Lawton, 1994; Galea & Kimura, 1993; Lawton, 1996; Lawton et al. 1996; O’Laughlin & Brubaker, 1998). According to Saucier et al. (2002), the different performances between males and females are not due to a better orientation ability in males rather than in females, but they are due to the different strategies employed. Males are likely to use survey strategies, which are usually more efficient than others. In the Saucier et al.’s (2002) experiment participants are requested to navigate to four unknown destinations. The location of each destination is determined by following some instructions. ‘‘Euclidean-based’’ instructions indicate the directions (e.g. north or west) and metric distances (e.g. 100 m). ‘‘Landmark-based’’ instructions indicate the salient landmark (e.g. the purple doors) and egocentric (right or left) turn directions. An error was scored when the participant took five or more steps in the wrong direction. The authors found that men perform best in navigational tasks when provided with Euclidean information, whereas women perform best when provided with landmark information. In fact, when instructions are ‘‘Euclidean-based’’, females make more errors than males for reaching the arrival point. When instructions are ‘‘landmark-based’’, males and females have similar performances.

In Sandstrom et al. (1998), when geometrical-configurational cues are available, males are faster than females at reaching a hidden target. When landmark cues only are available, no sex differences emerge. However, even if males prefer configurational strategies, they can use landmarks, when required. It seems that males can swap strategies if necessary, adapting dynamically their strategies to the information available in the environment. Females, on the other hand, are more landmark-centred and have more difficulties in swapping strategies. Thus males perform better in spatial orientation, because they spontaneously prefer configurational strategies (more complete than other strategies) and because they can swap easily their strategies, in line with to available information.

2.2.3. Personality factors

Another possible interpretation comes from psychological studies of personality. According to Lawton (1996) and Kozloswki and Bryant (1977) males are more confident than females about their skills in finding a way and about their own sense of direction. Similarly, self-evaluating questionnaires reveal that females are more anxious than males when navigating (Lawton, 1994).

The ‘‘spatial anxiety’’ (Lawton, 1994, 1996) or ‘‘fear to get lost’’ (Kozloswki & Bryant, 1977) can reduce the ability to focus on cues essential to maintain geographical orientation. Many studies find that stress impairs the ability to memorize spatial locations (Mackintosh, West & Saegert, 1975; Evans, Skorpanich, Gärling, Bryant, & Bresolin, 1984; Sunanda, Rao, & Raju, 2000). In Schmitz (1997), spatial anxiety and fear of the dark negatively correlate with speed in walking through a maze: subjects with high anxiety levels are the slowest. Anxiety about getting lost is likely to inhibit the exploration of unfamiliar places, having a negative impact on self-confidence and on motivation to navigate in new environments (Bryant, 1982, 1991). So females have few navigational experiences than males, having fewer opportunities to increase their spatial orientation skills.

Moreover, some studies demonstrate a relationship between spatial anxiety, kinds of strategy and orientation performance. In Schmitz (1997), males show low levels of anxiety and prefer to include more directional elements (configurational strategy) in verbal descriptions of a maze; they also perform better than females when running through a maze. Contrary to this, females show high levels of anxiety and include few directional elements and many landmarks in their descriptions. In agreement with these results, Lawton (1994) finds that the use of survey (configurational) strategies correlates negatively with the level of spatial anxiety. People with high level of spatial anxiety generally do not use this kind of strategy. These individuals are not able to maintain a sense of direction and/or self-position with respect to the surrounding environment (survey strategy). They tend to get lost, confused and anxious.

3. An interpretative hypothesis

All the previously reported hypotheses attempt to explain the presence of gender differences, ignoring the 40% of cases in which gender differences do not emerge. So far, there are no hypotheses that give a complete explanation of all emerged results. In an attempt to find a comprehensive explanation of the variability of the obtained results, we try to analyse literature from a different perspective, focusing on the cognitive demands of the orientation tasks, independently on the kind of tasks and on the kind of environment.

3.1. Gender differences in orientation emerge when tasks are "difficult"

From the previously analysed literature, it is possible to claim that when gender differences appear, they often arise favouring males. This tendency and the oscillation marked-differences/no-differences suggested to us that the difference in orientation performance could be "masked" by task-cognitive demands as follows: orientation tasks high in cognitive demands are accompanied by gender difference, orientation tasks low in cognitive demands are not.

In order to support the present hypothesis we show some examples grouped on the basis of tasks.

Verbal descriptions: Brown et al. (1998) found no differences between males and females in time spent to study a map and in errors giving verbal descriptions of a route within the map. Authors asserted that the absence of differences was due to the experimental paradigm used. It was a map-present paradigm, generating a low-memory load situation, since the map was always visible, when orientation tasks were executed. Similarly, Ward et al. (1986) found no gender differences in verbal descriptions of a route, when the map was present during task execution (easy task). Differences indeed emerged when the map was not visible, increasing the memory load of the tasks. Taylor and Tversky (1992b) found no gender differences in map drawings and in verbal descriptions. It is Taylor and Tversky's opinion that mean percentage of errors was very low for all subjects, both in map drawings and in verbal descriptions. It is possible to hypothesize that gender differences were "masked" or levelled-off by the low difficulty of the task. Again high performance can be ascribed to the experimental paradigm. Each participant studied twice the same verbally described environment, from two different viewpoints, a route perspective and a survey perspective. Furthermore, participants were free to study each perspective, for as long as they wanted and up to four times. This kind of procedure could generate an over–learnt situation.

Pointing: On the basis of significant differences in angular errors produced by all subjects when performing a pointing task, the Kirasic et al. (1984) identified "easy-to-locate" and "difficult-to-locate" landmarks. Post hoc analyses for each landmark showed significant differences in accuracy for locating the target. Some locations (difficult-to-locate landmarks) resulted in greater angular error than did others (easy-to-locate landmarks). Results showed that males located difficult landmarks with a lower angular error than females, and that gender differences disappeared when easy landmarks had to be located.

In Montello and Pick (1993), Sadalla and Montello (1989), and Kirasic et al. (1984) gender differences between males and females did not emerge in "real test pointing". These results can appear completely incompatible if we do not consider participants' familiarity with the environment. In all these studies, in fact, participants were students and the environments were familiar buildings in campus. We suggest that the absence of gender differences might be due to the high familiarity of the subjects with the environment. In particular, Kirasic et al. (1984) chose their landmarks for the pointing task, just on the basis of familiarity data from a previous study (Herman, Kail, & Siegel, 1979).

Distance estimation: Both in Galea and Kimura (1993) and in Coluccia and Martello (2004), gender differences for straight-line judgment tasks did not emerge. These results are inconsistent with the well-known male-superiority in all Euclidean tasks. Usually Euclidean tasks require estimating the absolute distance between two or more objects (Miller & Santoni, 1986; Geary, 1995; Dabbs et al., 1998). The absence of gender differences in Galea and Kimura (1993) and in Coluccia and Martello's (2004) study could depend on the type of task. In both these studies participants were not required to produce metrical estimations, but to make a comparison between two (Galea & Kimura, 1993) or three (Coluccia & Martello, 2004) positions (i.e. "Starting from landmark A, which landmark is more distant? B or C?"). Making a qualitative distance comparison is easier than making a quantitative distance estimation (i.e. "How meter/miles far is A from B?"). Gender differences again dissolve in low-demanding tasks.

Wayfinding: Lawton et al. (1996) did not find gender differences in the route-reversal task. Participants were instructed to walk in a real indoor environment, retracing backward a route from the end to the starting point. Differences did not arise both in time spent and in number of errors. Lawton et al. (1996) suggested that gender differences in wayfinding could be found in an environment characterized by a more complex structure than the used one. In fact, Lawton et al. (1996) admitted that in the environmental structure of their research there were only a few routes that could be taken to go back to the starting point, spending a short time. Lawton et al. (1996) concluded that, in order to obtain gender differences in wayfinding, it is necessary to use more complex environments.

Various tasks: In Coluccia and Martello (2004), two different maps were used: the first was characterized by a regular pattern of routes with straight, perpendicular and parallel streets, square-shaped zones and landmarks with similar features. The second map was characterized by an irregular pattern of routes with dissimilar and curvilinear streets and different types of landmarks. Following map learning subjects were required to perform 8 orientation tasks: Landmark Recognition; Landmark with Surrounding Recognition; Map Completion; Map Section Rotation; Euclidean Distance Judgement; Route Recognition; Wayfinding; Route Distance Judgement. It was found that subjects showed greater overall orientation performance in the irregular map than in the regular one. Significant gender differences emerged with the regular (more difficult) map, but not the irregular (easy-to-learn) map. Some tasks in particular showed marked gender differences: Landmark with Surrounding Recognition; Map Completion; Route Recognition; Wayfinding; Route Distance Judgement (see Bosco, Longoni, & Vecchi, 2004 for an exhaustive description of the tasks).

A last hint comes from spatial ability literature. In the meta-analysis by Linn and Petersen (1985), the largest difference between males and females was found in the Mental Rotation Tests. This kind of task is supposed to be the most difficult in comparison to the other two types found by the authors (Spatial Visualization Tests and Spatial Perception Tests). All the three spatial ability tasks require the production of a mental image, but the Mental Rotation Tests need an additional process, because three- or two-dimensional objects have to be rotated in imagination.

3.2. The difficulty of the task depends on its working memory load

When analysing gender differences, an important factor is the working memory load. According to Thorndyke and Hayes-Roth (1982) and Rossano and Moak (1998), a real test has a lower cognitive load than a simulated test. In a simulated test participants are required to make a consistent imagination effort. The cognitive load, in fact, increases depending on the number of interacting elements to be maintained simultaneously in working memory (Marcus, Cooper & Sweller, 1996). In a real pointing task, for instance, subjects are positioned in a specific point at the environment, facing a specific direction. Then, they are asked to point at some landmarks direction. In a simulated test, on the other hand, subjects are set down in front of a desk, facing up a wall of the room. Then they are asked to imagine staying in a different location, with his/her face towards a specified direction and to point at some landmarks.

In simulated tasks, females often show lower performance than males. In real tasks their performance is similar to male ones (Rossano & Moak, 1998). Brown et al. (1998) found that gender differences disappeared, when the memory load is low (map present condition). Similarly, Ward et al. (1986) did not find gender differences in map present condition (low memory load). Males performed better than females when the map was absent (high memory load).

According to Garden, Cornoldi, and Logie (2002), the memory load implied in wayfinding processes is not a generic cognitive load, but it is a specific load of Visuo-Spatial Working Memory (VSWM). Consequently, gender differences could arise in spatial orientation tasks that require a consistent load of VSWM. Using dual task methodology, Garden et al. (2002) showed that spatial tapping (VSWM interference tasks) impaired performance in a route-recognition task significantly more than articulatory suppression (Verbal Working Memory interference task) did. These results reveal the direct implication of VSWM in orientation abilities. Other studies are also consistent with these conclusions. Conte, Cornoldi, Pazzaglia, and Sanavio (1995), found that blind boys with high working memory perform better than girls when moving through a room. Pazzaglia and Cornoldi (1999) found that participants with high scores in the Corsi test have an optimal memory for route descriptions. Then, Bosco et al.(2004), using multiple regression approach, found that some VSWM tasks predict orientation performance.

Can we hypothesize that gender differences emerge only in high-VSWM-load tasks because women's VSWM are less efficient? In fact, many studies found that females have a lower VSWM span than males (Richardson, 1991; Halpern, 1992; Lawton & Morrin, 1999). These span differences are particularly marked in active tasks, where participants are required to elaborate, integrate and transform the visual imagined material (Vecchi & Cornoldi, 1998; Vecchi & Girelli, 1998).

4. Conclusion

It seems that marked gender differences in VSWM can account for some differences in the orientation abilities. In particular, gender differences in orientation emerge only when tasks require a high load of VSWM. Consequently the VSWM load could be a determinant factor, able to increase or level off individual differences in orientation abilities. Males would show better orientation performance, because of their larger VSWM span. When the orientation task does not involve a high load in VSWM, gender differences would disappear.

The interpretation we are offering in this review is not expected to be exhaustive, since we do not try to explain the origin of the gender differences in WM. More simply the present review wants only to offer an hypothesis helpful in the understanding of the overall findings, trying to cast more light on the large variability of the results emerged.

Spatial orientation is a healthily multi-disciplinary area: the collaboration between psychologists and geographers is crucial for the development of spatial orientation studies. As stated by Kitchin, Blades, and Golledge (1997): "Both psychologists and geographers have much to offer each other, in terms of ideas, theory, and methodologies". In order to understand more fully our behaviour in space, the integration of environmental psychology and behavioural geography is essential (Kitchin et al., 1997).

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