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Besides navigation accuracy: Gender differences in strategy selection and level of spatial confidence

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ABSTRACT

A virtual version of the reorientation task was employed to test new behavioral measures of navigation strategies and spatial confidence within a gender-fair assessment approach. The results demonstrated that, from a behavioral point of view, women had lower level of spatial confidence than men regardless of level of accuracy. Moreover, the way men and women selected spatial strategies depended on the arrangement of spatial cues within the environment. In other terms women relied on landmarks under specific conditions compatible with an adaptive combination/associative model of spatial orientation. Finally, the present study emphasized the importance to assess gender differences taking into account specific affective variables and information selection processing, beyond accuracy.
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1. Introduction

Spatial orientation is one of the most critical skills in which sex differences, favoring males, are largely documented in all mobile creatures (e.g. Saucier, Shultz, Keller, Cook, & Binsted, 2008; Barkley & Jacobs, 2007; Forcano, Santamaria, Mackintosh, & Chamizo, 2009; Sovrano, Bisazza, & Vallortigara, 2003; Astur, Ortiz, & Sutherland, 1998; Gyselinck, Picucci, Nicolas, & Piolino, 2006). Nevertheless, human research reveals a more nuanced pattern of results than a simple claim of a male superiority. In fact, gender differences in orientation tasks show a large variability (for a review Coluccia & Louse, 2004) that might reflect the multi-component nature of spatial performance (e.g. Wolber & Hagarty, 2010; Botella, Peña, Contreras, Shih, & Santacreu, 2009). Three different cognitive factors might contribute to clarify various aspects of gender differences in spatial orientation, that is, the ability (e.g. Astur et al., 1998; Miller & Santoni, 1986), the strategies adopted to solve the task (e.g. Sandstrom, Kaufman, & Huettel, 1998) and the affective components, i.e. self-confidence (e.g. Bryant, 1991). In particular, the *ability* can be referred as the level of achievement reached by men and women in solving the task and specifies "who is the best at". It is often evaluated in terms of accuracy by measuring variables such as time taken, path lengths, number of wrong directions, number of correct answers.

Spatial strategy, on the other hand, is referred to a quite stable proneness to adopt more readily a class of spatial information or a model of spatial reasoning in order to solve a task (e.g. Cooper & Mumaw, 1985). It regards "how individuals solve a task" and does not imply by itself the concept of achievement (Bosco, Longoni, & Vecchi, 2004; Lawton, 1994, 1996; Sandstrom et al., 1998; Saucier, Green, Leason, & MacFadden, 2002). Converging data, within strategy selection topic, reveal that men and women rely on different spatial cues when navigating (such as) a) *geometric* and *feature*, b) *directional* and *positional* and c) *holistic/configurational* and *analytic/landmark* respectively (e.g. Sandstrom et al., 1998; Barkley & Gabriel, 2007; Glück & Fitting, 2003; Ruggiero, Sergi, & Iachini, 2008; Coluccia, Bosco, & Brandimonte, 2007; Ward, Newcombe, & Overton, 1986). Nevertheless, following the *adaptive combination model*, factors such as *cue salience*, *encoding certainty* and *cue validity* might affect gender differences more than cue type *per se* (Kelly, McNamara, Bodenheimer, Carr, & Rieser, 2009; Kelly & Bischof, 2005; Learmonth, Newcombe, Sheridan, & Jones, 2008; Ratliff & Newcombe, 2008).

Level of spatial confidence also might affect gender differences in spatial performance as it plays a role in determining the emotional appraisal in approaching orientation task (e.g. Moè & Pazzaglia, 2006; Parsons, Adler, & Kaczala, 1982; Schmitz, 1997). Self-confidence usually refers to the beliefs that people have about their own capacities in any kind of tasks. It strongly derives from social expectation, gender beliefs, personal and vicarious experiences (Hackett & Betz, 1981). A strong impact of level of spatial confidence has been showed in both psychometric and navigation assessment (e.g. Bryant, 1991; Cooke-Simpson & Voyer, 2007; Moè & Pazzaglia, 2006; Wraga, Duncan, Jacobs, Helt, & Church, 2006). One common use of level of confidence assumes that it reflects

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memory strength. However previous studies, in different domains, have shown behavioral dissociations between confidence and accuracy (Busey, Tunnicliff, Loftus, & Loftus, 2000; Chua, Schacter, Rand-Giovannetti, & Sperling, 2006), suggesting that they may not be based on entirely the same information. With regard to spatial performance, Parsons et al (1982) demonstrated that women showed lower levels of confidence in their ability to solve spatial tasks even when they perform as well as men (e.g. O'Laughlin & Brubaker, 1998; Beyer & Bowden, 1997).

Literature on gender differences has often focused on identifying who was more adept at solving a task (e.g. Hyde, 2005). According to this intent, highly taxing tasks (e.g. Vecchi & Girelli, 1998; Coluccia & Louse, 2004) have been frequently adopted. In these kinds of tasks, however, the specific contribution of factors affecting spatial performance (i.e. accuracy, strategies and levels of confidence) is hard to interpret. For instance, as task difficulty increases, spatial strategy selection impacts strongly the performance (e.g. Peña, Contreras, Shih, & Santacreu, 2008; McNamara & Scott, 2001). Moreover, when a task is perceived as particularly challenging, gender differences in spatial performance are strongly affected by the trust in its own skills (e.g. Moè & Pazzaglia, 2010). As a matter of facts, aiming to stress gender differences can also lead to disregard *gender-fair assessment* criteria. According to Willingham and Cole (1997), men and women should be tested on "what they are good at". Conceptualizing test fairness as a feature of test validity, the authors suggest a series of criteria that are: a) comparable opportunities for examinees to demonstrate relative proficiency, b) comparable exercises and scores and c) comparable treatment in interpreting the data (p. 359). Gender-fair assessment in virtual navigation tasks, for instance, is promoted whenever a) an adequate training with technological tools and environments is provided and b) instructions are adequately thought to be unbiased for both men and women (e.g. Cherney, 2008; Chilisa, 2000; Campbell & Greenberg, 1993). Moreover, Moè and Pazzaglia (2006) have suggested that gender stereotypes can be manipulated through the instructions overturning gender effect on spatial performance. On the contrary, underestimating gender-fair assessment criteria can lead to maintain social stereotypes (e.g. Cheryan & Bodenhausen, 2000; Schmader, 2002; Maass & Cadinu, 2003). In this view, some important assessment methods in gender research might pay little attention to these criteria developing tasks that differently tax genders. For instance, women have been demonstrated to be slower than men (e.g. Picucci et al., 2010; Cazzato, Basso, Cutini, & Bisiacchi, 2010; Banta Lavenex & Lavenex, 2010; Astur et al., 1998; Woolley et al., 2010), and to became more anxious when the time available is limited (Gavrielidou & Lamers, 2010; Kara, Hong, Chandra, Longborn, & Barkley, 2010). The performance in the widely used water-maze-like tasks (Astur et al., 1998; Morris, Garrud, Rawlins, & O'Keefe, 1982) is based specifically on the time spent and the path covered. As a consequence, the aforesaid systematic differences might threaten the equal opportunity to succeed in this kind of tasks.

The aims of the present study are manifold: a) to confirm the previous studies on substantially equal ability of men and women in the reorientation task, b) to evaluate the fairness of this kind of assessment procedure, and c) to promote two new behavioral measures: spatial strategy and self confidence. In particular, women are expected to adopt, if possible, a landmark strategy. According to the adaptive combination model (e.g. Kelly et al., 2009; Learmonth et al., 2008), they would follow this strategy essentially when landmark is considered as a stable benchmark. Men, on the other hand, would be less sensitive to the stability of landmark and would adopt spatial strategies in a more flexible manner (e.g. Castelli, Latini Corazzini, & Geminiani, 2008) showing to employ both landmark/feature and geometric strategies.

1.1. The experiment

The present study evaluates the contribution of the aforementioned components in spatial orientation performance adopting a gender-fair assessment. Reorientation paradigm (e.g. Hermer & Spelke, 1994, 1996) seems a suitable tool to reach this goal. It is a searching task allowing to assess the ability to use different sources of spatial information (i.e. geometrical, featural or both) after a disorientation procedure. The main assumption of this paradigm is that individuals and non-human animals can rely on two sources of information, i.e. information given by the shape of the environment and information given by the features (visual, auditory, olfactory, haptic cues), in order to reorient after being disoriented. A typical reorientation task, as described in Cheng (1986) and in Hermer and Spelke (1994, 1996) consists of: a) a learning phase, in which participants are free to navigate and explore an environment, and have to encode the location of a target stimulus (i.e. a source of food for rats, a toy for children, a distinctive object for adults), b) a disorientation phase, in which participants are blindfolded and rotated on themselves, thus perturbing their self reference system, and c) a testing phase, in which participants have to navigate the environment and find the hidden target previously shown. A virtual implementation of reorientation paradigm (VRP) already employed in Bosco, Picucci, Caffò, Lancioni, and Gyselinck (2008), Picucci, Caffò, and Bosco (2009), Picucci et al. (2010), Picucci and Bosco (2006) is adopted. To date, a direct comparison between real and virtual versions of reorientation paradigm is not available. Nonetheless, Picucci (2008, unpublished doctoral dissertation), trough a Goodness of Fit Analysis, demonstrated that Hermer and Spelke's results (1996) on the real version of the task were comparable with those obtained on VRP. As a matter of facts, the VRP is a virtual analogue of the original paradigm which allows to obtain a suitable experimental control on the procedure (Bosco et al., 2008; Picucci et al., 2010). It also allows a new methodology allowing to behaviorally specify/separate abilities from spatial strategies and level of self-confidence. This is particularly noticeable since usually self-report questionnaires have to be employed, in combination with experimental manipulations, to obtain an assessment of strategies and affective factors. Adopting these behavioral measures may prevent from biases commonly found in self-report questionnaire and favoring a more reliable assessment of components affecting spatial performances as they are actually expressed by participants during the task. In addition, the adoption of VRP may fill the lack of systematic studies on gender differences in this research paradigm (e.g. Cheng & Newcombe, 2005; see also Voyer, Postma, Brake, & Imperato-McGinley, 2007). The VRP seems suitable to ensure a gender-fair assessment providing the same starting condition for both men and women since a) participants did not have to recur to metric/coordinate information in order to locate the target (e.g. Iachini, Sergi, Ruggiero, & Gnisci, 2005), b) landmark was presented in a stable manner (e.g. Kelly & Bischof, 2008), and c) time and path did not influence the measuring of accuracy. Ability, strategies and level of spatial confidence were the main measures taken into account in the present study. In order to control for fairness, the performance was properly evaluated to show men and women were able to reach the excellence in a comparable manner. At the same time, path travelled and time taken are not considered as critical markers of spatial ability. As mentioned above, women are slower than men and become anxious in time limited tasks (e.g. Gavrielidou & Lamers, 2010; Picucci et al., 2010; Cazzato et al., 2010). In the present study, results on time and path are provided as variables supporting the internal validity of the paradigm and completing the sight on gender-related differences in this spatial navigation task (e.g. Glück & Fitting, 2003; Picucci et al., 2009). Accuracy was evaluated in terms of number of correct searching.

Iachini et al. (2005) and Kelly and Bischof (2008) suggested that gender differences are not expected if tasks adopt a categorical frame of reference (i.e. the ability to encode relationships between objects in a discrete and relational rather than in a metric, fine-grained manner, e.g. Kosslyn, 2006). The level of spatial confidence was evaluated in the room where geometry is the unique spatial cue available. The expectation is that women are less confident than men (see also Schmitz, 1997; Lawton, Charleston, & Zieles, 1996). Spatial strategies selected by men and women were assessed presenting information as single cues (as in Kelly et al., 2009) or conjoined (as in Sandstrom et al., 1998). A new condition, specifically a square room containing a landmark, was introduced in order to isolate the effects of featural information on spatial performance. Furthermore, for both square and rectangular rooms, the spatial relation between landmark and target was manipulated as *positional* (near to) or *directional* (far from) cues. Women are expected to rely more on positional cues compared to men (e.g. Barkley & Gabriel, 2007) and both of them to engage in different strategies depending on the different weight of cues within the environment (e.g. Kelly & Bischof, 2008).

2. Method

2.1. Participants

Ninety-six participants were originally recruited for the experiment. Data of five participants (three men and two women) were eliminated from the sample since they did not reach the proficiency in using the apparatus. The final experimental sample was composed of forty-six women ranging in age from 23 to 27 ($M = 25.2$; SD = 1.4) and forty-five men ranging in age from 23 to 28 ($M = 26.4$; SD = 1.2). Participants were recruited from introductory courses of Psychology at the University of Bari and received an extra course credit in exchange for participating. The vision of all participants was normal or corrected to normal.

2.2. Apparatus and materials

An extended description of the apparatus used here was included in Bosco et al. (2008). Freeware software, the C-G Arena was used (e.g. Jacobs, Laurenche., & Thomask, 1997). A computer monitor (19" wide) displayed an environment in a first-person perspective view. The environment had an internal structure composed by a circular, invisible arena, in which the participants could move and explore freely controlling their movements with a joystick. Two kinds of environments were created: a rectangular environment with proportion of 2:3 as proposed in the original experiment of Hermer and Spelke and a square environment measuring as the short side of rectangular one. Five experimental conditions, three for rectangular rooms and two for square room, were generated. One rectangular room was arranged with four white walls and two with a blue wall on one of the short side. The two square rooms had a blue wall on one of the sides. Rooms housing the blue wall were presented in two different ways according to the spatial relationship between the blue wall and the searching object. It could be positioned next to the blue wall or far from it. Experimental session counted in twenty-five trials, five for each environment.

2.3. Procedure

Each participant entered into the laboratory and sat on a chair in front of a computer screen and a joystick. After reading and signing a consent form, participants received standardized verbal instructions about how to move within the space in each task (for a description of instructions: Bosco et al., 2008). Participants were also asked to fill in a short questionnaire about their experiences with personal computers, videogames and console games. Participants marked the frequency with which they used these tools (0: never; 1: rarely; 2: occasionally; 3: frequently) on a four-point Likert-type scale. The level of experience with a joystick can determine relevant gender differences in performance in the virtual navigation tasks (e.g. Feng, Spence, & Pratt, 2007). A measure of self-confidence about spatial orientation ability was also obtained by asking participants a single question (Kozlowski & Bryant, 1977): "How much do you trust in your spatial orientation ability?". Participants had to rate their level of confidence on a 7-point scale (1 = poor; 7 = good).

2.3.1. Training phase

Prior to the start of the experiment, all participants were requested to gain experience with the desktop virtual environment apparatus in order to reach an adequate level of practice. The training phase was carried out in order to avoid or to minimize distortions due to different level of experience when facing a virtual reality apparatus (e.g. Cherney, 2008). When participants felt comfortable with controlling their movements through the environment, they were allowed to access to the experimental session.

2.3.2. Experimental session

Each trial displayed a learning and a testing phase separated by a black screen interval of approximately two seconds. Participants entered the learning environment which contained a yellow sphere placing in one corner and four black response patches locating on the floor. They faced randomly one of the four walls. In this phase, participants were explicitly requested to look for the yellow sphere. When they felt comfortable with the task, they gave a signal to the research assistant, who promptly pressed the space bar and teleported the participants into the testing environment. During the interval between learning and testing phase, the computer screen was switched-off. The C-G Arena application allowed participants' facial position to be randomly changed in order to interfere with the egocentric mental representation. Entering the testing room, participants could reorient and find the sphere adopting an external frame of reference. The testing environment had the same characteristics of the learning environment with the following exceptions: the sphere was replaced by a blue box and three identical boxes were located in other corners. Participants were informed that the yellow sphere was hidden but not moved from the original location and they were requested to discover the box housing the sphere by reaching the response patch corresponding to that box. A new trial could only begin if the participants were able to reach the correct response patch as in a typical searching task. Participants faced five types of environment (see Fig. 1): one rectangular room with all white wall, two rectangular rooms with a blue wall placed near or far from the target; two square rooms with a blue wall placed near or far from the target. Twenty-five trials were presented in a pseudo-random order. The program recorded a large amount of data. The relevant ones for our aims are collected in the testing phase.

2.4. Statistical analysis

2.4.1. Analysis on fairness

Analysis on fairness of tasks was run for each experimental condition on 2 × 2 contingency tables with gender and level of performance as between-subjects factors. The latter one was previously dichotomized as following: participants who completed the task without errors versus those who made at least one error. The rationale is to evaluate whether the tasks allow women as well as men to reach the full proficiency with a comparable probability. Noticeably, this analysis did not overlap with that on accuracy.

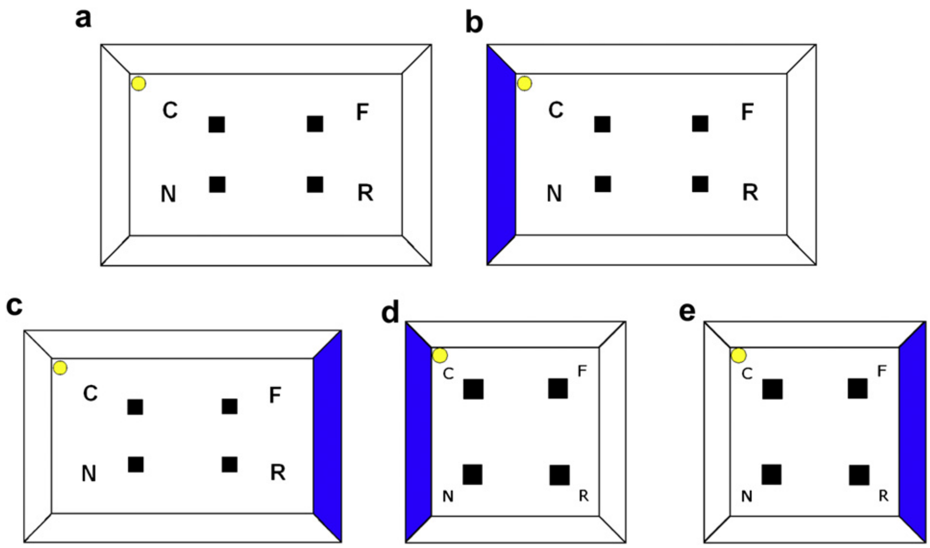

Fig. 1. Overhead view of the experimental rooms. (a) Rectangular room with all white walls - RA. (b) Rectangular room with three white walls and one colored wall near to the target - RP. (c) Rectangular room with three white walls and one colored wall far from the target - RD. (d) Square room with three white walls and one colored wall near to the target - SP. (e) Square room with three white walls and one colored wall far from the target - SD. Correct corner, hosting the target, is coded as "C". The other corners are coded on respect to C as "N" (near to C); "R" (rotationally equivalent) and "F"(far from C).

Then, five Fisher's Exact Probability Tests were performed. They returned the probability to obtain the observed 2×2 contingency table by counting all possible tables that can be constructed based on the marginal frequencies, under the null hypothesis that there is not relationship between factors. Here, it was evaluated a non directional, two-tailed hypothesis.

2.4.2. Accuracy

This analysis was run on participant's first search in order to verify the accuracy in solving the task. In rectangular all white-walls environment, the responses were recorded as appropriate if the participants searched either at the correct corner "C" or at its rotationally equivalent "R" corner (see Fig. 1a). In all the other rooms the responses were recorded as appropriate if the participants searched at the correct corner "C".

2.4.3. Analysis of time and path

Time spent and path travelled by participants were assessed when participants reached the correct patch at first searching. This kind of analyses was run in order to evaluate possible gender differences in navigation without any errors increasing the latency and the path length.

2.4.4. Analysis of response pattern

The assessment of this dependent variable gives us the opportunity to verify two relevant aspects in gender differences research: the level of confidence felt by men and women during their performance and the spatial strategies adopted by the participants while facing the task. Self confidence is behaviorally evaluated in that environment containing geometric information (Miller & Shettleworth, 2007). Visiting "R" corner is, in terms of accuracy, the appropriate behavior (see Fig. 1a). However, according to the original paradigm, participants stopped their searching only if they reached the "C" angle. In our view, the participants more confident with their spatial representation should have followed the pattern "RC". On the other hand, the participants were considered less confident if they become prone to reach other corners than "C" (i.e. "N" or "F") as discouraged by the lack of reward in "R" corner.

Spatial strategies analysis was carried out on the first and second responses if a wrong searching occurs as first. The ratio of this choice was the following: imagine a participant that, failing to reach the correct corner "C", heads for the "N" one (see Fig. 1b). Scoring only the "N" response, it is possible to simply conclude that a participant is able to recover very basic categorical information such as "target is near to/far from the landmark". Nonetheless this information may be used in an incomplete way that forgets the *sense* relationship ("left/right") between target and landmark. It may be asserted that he/she is following a strict landmark strategy only if the second search corresponds to the correct corner "C". Consequently, it may be considered that the "NC" response pattern is a coherent, spatial, *landmark-guided* strategy. Other possible response patterns (i.e. "NR" or "NF") might be thought as *guessing* strategies (e.g. Cooke-Simpson & Voyer, 2007) since after a response calling for a landmark-guided strategy (first search in "N"), participants indulged in a second error ("R" or "F") incompatible with an idea of a coherent landmark-guided strategy. When facing the rectangular room with the blue wall, participants could also follow "RC" pattern coded as *layout guided strategy*. In the square rooms, layout was absent and the only two available strategies were *landmark guided* and *guessing strategies*. In conclusion, if only the first response is taken into consideration, it leads to an unreliable definition of spatial strategies adopted during this task.

3. Results

3.1. Computer/gaming experience

Women and men did not differ significantly in their report of computer, joystick, and computer gaming experience. Mean rating of computer gaming experience was comparable, $t(89) = 0.66$, $p = 0.50$, for women ($M = 2.3$, SD $= 0.7$) and men ($M = 2.4$, SD $= 0.6$).

3.2. Analysis on fairness

Five two-tailed-Fisher's exact p tests were performed, one for each experimental condition. Results showed that men and women did not differ in the opportunity to reach a full proficiency in each of the tasks considered (see Table 1).

Table 1
Two tailed Fisher Exact p ($N = 91$) as effect of gender and level of performance. Best performers (no errors) were indicated as "$P = 1$". All the others (at least one error) were indicated as "$P < 1$". RA geometric information only, RP geometric and landmark (near to target) information, RD geometric and landmark (far from target) information, SP landmark (near to target) information only, SD landmark (far from target) information only.

Environment	Women				Men				P
	$P = 1$		$P < 1$		$P = 1$		$P < 1$		
	n	%	n	%	n	%	n	%	
RA	19	20.9	27	29.7	28	30.8	17	18.7	0.06
RP	37	40.7	9	9.9	36	39.6	9	9.9	1.00
RD	25	27.5	21	23.1	30	33.0	15	16.5	0.28
SP	40	44.0	6	6.6	39	42.9	6	6.6	1.00
SD	17	18.7	29	31.9	17	18.7	28	30.8	1.00

3.3. *Accuracy*

A one-way ANOVA was performed in order to evaluate gender differences in all white wall room (see Table 2). The dependent variable was the mean proportion of correct responses obtained adding first searches in C and R angles. The effect of gender was not significant. The performance in the blue-wall rooms was evaluated trough a $2 \times 2 \times 2$ mixed factor ANOVA carried out on proportion of correct responses (see Table 2). The variables included were gender (men, women) as between variables; shape of the environment (Rectangular and Square) and spatial relation between landmark and target (near to and far-from) as within variables. A main effect of spatial relation between landmark and target emerged, $F(1, 89) = 54.56$; $p < 0.001$, $\eta_p^2 = 0.38$, showing that performance get worse when landmark and target were not directly associated (M near-to = 0.95; M far-from = 0.83). A first-order interaction emerged for gender and shape, $F(1, 89) = 6.5$; $p < 0.05$, $\eta_p^2 = 0.06$. In particular, men ($M = 0.93$) outperformed women ($M = 0.87$) in rectangular rooms. Another first-order interaction emerged for gender and spatial relation between landmark and target, $F(1, 89) = 5.6$; $p < 0.05$, $\eta_p^2 = 0.06$, men ($M = 0.87$) performed better than women ($M = 0.79$) if the landmark was far from the target.

3.4. *Analysis of time and path*

Two one-way ANOVAs were performed on time spent and path covered in the testing room when participants reach the target at first searching. As for the previous analysis, visiting "R" corner in all white wall rooms was considered a correct response as well. With regard to time spent to reach the target, a significant effect emerged, $F(1, 89) = 8.7$; $p < 0.01$, $\eta_p^2 = 0.09$, showing that females took more time to give the correct responses ($M = 4.9$ s) compared to males ($M = 3.2$ s). A similar pattern of results was found when path length was assessed $F(1, 89) = 10.15$; $p < 0.01$, $\eta_p^2 = 0.10$; females ($M = 152.7$ units), compared to males ($M = 105.9$ units), covered longer route to reach the target.

In blue wall rooms, two $2 \times 2 \times 2$ mixed factor ANOVAs were carried out on time and path separately. The variables included were gender (Male, Female) as between variables; shape (Rectangular and Square) and spatial relation between landmark and target (near to and far-from) as within variables. With regard to time, a significant gender effect emerged $F(1, 89) = 24.5$; $p < 0.001$, $\eta_p^2 = 0.22$ showing that males ($M = 1.5$ s) resolved the task faster than females ($M = 1.9$ s). In addition, participants solved faster the task in near to ($M = 1.6$ s) on respect to far-from condition ($M = 2.0$ s) ($F(1, 89) = 82.82$, $p < 0.001$, $\eta_p^2 = 0.48$). An analogous pattern of results emerged for path length analyses. Males ($M = 51.7$ units) walked less than females ($M = 58.2$ units) and this effect was significant ($F(1, 89) = 5.8$, $p < 0.05$, $\eta_p^2 = 0.06$). In addition, a main effect regarding the spatial relation between landmark and target emerged, $F(1, 89) = 13.6$, $p < 0.01$, $\eta_p^2 = 0.13$, showing that when landmark and target were directly associated ($M = 53.4$ units), participants solved the task travelling less than in far-from condition ($M = 60.2$ units). No interaction effect emerged in these statistical analyses.

3.5. *Analysis of response pattern*

3.5.1. *Level of spatial confidence*

The level of spatial confidence was evaluated by means of two different methods. In particular, it was behaviorally inferred by the pattern of response provided by participants during the reorientation task and by a self-report measure. The behavioral measure of spatial confidence was obtained combining the first two responses when participants chose corner "R" as first. Preliminarily, we checked the degree of overlap between accuracy ("C" *or* "R" as first choice) and spatial confidence (proportion of "R" *and* "C" as first two choices). The Pearson's r between these measures is equal to 0.21 ($t(79) = 1.92$, $p < 1$). Then, an unpaired t-test was used to assess the level of spatial confidence showed by males and females while coping with geometric information. The dependent variable was the proportion of "RC" pattern of response. The sample in this analysis was downsized to eighty-one individuals: three females and seven males never reached the "R" corner as their first searching. The analyses shows a significant effect, $t(79) = 2.34$; $p < 0.01$ $d = 0.53$ demonstrating that men ($M = 0.74$; SD = 0.41) follow "RC" pattern more than women ($M = 0.53$; SD = 0.39). The rate of the self-report measure of spatial confidence, $t(89) = 3.54$; $p < 0.01$ $d = 0.56$) demonstrated that men ($M = 5.68$; SD = 1.17) were significantly more confident than women ($M = 4.82$; SD = 1.14). The Pearson's r between self-report and behaviorally inferred measure of spatial confidence is 0.49, $t(79) = 4.99$, $p < 0.01$.

Table 2
Mean (standard errors) of the dependent variables as effect of the kind of environment and gender ($N = 91$). RA geometric information only, RP geometric and landmark (near to target) information, RD geometric and landmark (far from target) information, SP landmark (near to target) information only, SD landmark (far from target) information only. Accuracy is referred to the proportion of correct searches. Time spent (in seconds, calculated only for correct searches) is referred to the time to reach the response patch. Path Length (in units of space, calculated only for correct searches) is referred to the path covered to reach the response patch.

	RA	RP	RD	SP	SD
Accuracy					
Women	0.82 (0.02)	0.94 (0.01)	0.79 (0.03)	0.97 (0.01)	0.80 (0.02)
Men	0.86 (0.03)	0.95 (0.01)	0.91 (0.03)	0.95 (0.01)	0.83 (0.02)
Time spent					
Women	4.91 (0.43)	1.85 (0.08)	2.14 (0.06)	1.69 (0.06)	2.20 (0.09)
Men	3.08 (0.44)	1.45 (0.08)	1.76 (0.06)	1.37 (0.06)	1.79 (0.08)
Path length					
Women	152.76 (10.32)	53.87 (2.38)	58.45 (3.16)	58.14 (3.78)	62.38 (3.7)
Men	105.92 (10.4)	48.7 (2.44)	52.60 (3.1)	43.60 (3.1)	61.91 (3.8)

3.5.2. Spatial strategies

For the present analysis, the sample was downsized to seventy participants since twelve women and nine men performed the whole task without errors. As previously reported, three strategies were expected in the rectangular room. However, *layout guided strategy* was completely lacking in both near to and far-from conditions. Spatial strategies were evaluated trough a $2 \times 2 \times 2 \times 2$ mixed factor ANOVA carried out on proportion of errors. The variables included were gender (Male, Female) as between variables; shape of the environment (Rectangular and Square), spatial relation between landmark and target (Near-to and Far-from) and strategies (Landmark-guided Strategy and Guessing Strategy) as within variables. The third-order interaction was significant: $F(1, 68) = 5.76$; $p < 0.01$; $\eta_p^2 = 0.08$. Four planned comparisons with gender and shape of the environment as factors were then performed in order to clarify the meaning of this interaction. The most relevant comparisons were those involving the far-from target environments. In particular, women adopted significantly more than men the landmark-guided strategy in the rectangular rooms, $F(1, 68) = 11.27$; $p < 0.001$; $\eta_p^2 = 0.14$ (see Fig. 2, lower left). At the same time, they adopted the guessing strategy, more than men in the square rooms, $F(1, 68) = 8.27$; $p < 0.005$; $\eta_p^2 = 0.10$ (see Fig. 2, lower right). Finally, a series of Pearson's r was performed on behaviorally measured self-confidence and measures of guessing strategy for each environment. Values of correlation coefficients varied between -0.14 and -0.23. None of them reached the statistical significance.

4. Discussion

The aim of the present study was to assess gender differences adopting new behavioral measures to capture spatial strategies and levels of spatial confidence experienced by participants during a searching task involving virtual navigation. The present aim was pursued taking into account gender fairness criteria. Nonetheless, other typical measures such as accuracy, path and time have been assessed in order to be consistent with previous studies on spatial orientation (e.g. Hermer & Spelke, 1994; Bosco et al., 2008).

4.1. Gender fairness

A series of two-tailed-Fisher's Exact p on each of five environments showed that men and women can reach the maximum level of proficiency with the same probability. This result allows to conclude that the virtual reorientation task is suitable to assess gender differences according to the gender fairness criteria (e.g. Willingham & Cole, 1997; Hyde, 2005; see also Bosco et al., 2004).

4.2. Accuracy

According to Sandstrom et al. (1998) and Saucier et al. (2002), women relied more on landmark information and perform poorly when spatial navigation was guided by geometric cues. However, this study showed that the ability of women in managing geometrical information could vary as effect of environmental characteristics. In particular, when men and women were provided with information about the only geometry, women performed as well as men, confirming previous data of Kelly et al. (2009) in a locomotion/egocentric task. If a landmark was presented, women relied on this cue (square room = rectangular room), on the other hand, men benefited larger than women of the presence of two conjoined cues (square room < rectangular room). These results demonstrated that women are able to use the geometric cue but they almost totally neglected this information when landmark was added in predicting the target. Men, on the contrary, were able to dynamically integrate spatial information available in the environment (e.g. Saucier et al., 2002; Dabbs, Chang, Strong, & Milun, 1998). As in previous studies the manipulation of the relationship between landmark and target produced a well-known effect (e.g.

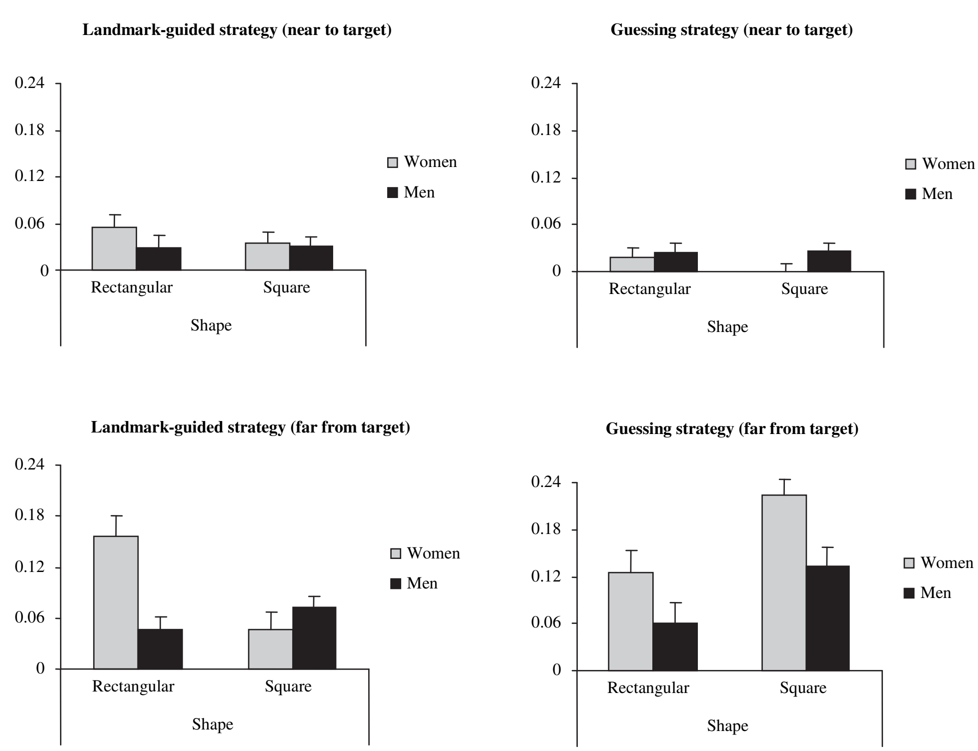

Fig. 2. Mean proportion (bars are standard errors) of: landmark-guided errors in near-to-target condition (upper left); guessing errors in near-to-target condition (upper right); landmark-guided errors in far-from target condition (lower left); guessing errors in far-from target condition (lower right), as effect of gender and shape.

Bosco et al., 2008; Artigas, Aznar-Casanova, & Chamizo, 2005). The distance between landmark and target impaired spatial performance and this effect was slightly larger for women. This finding was consistent with female's preference for positional with respect to directional landmarks as previously stated by Chai and Jacobs (2010), Barkley and Gabriel (2007), Jacobs and Schenk (2003), reflecting the evolutionary theory of gender roles proposed by Silverman and Eals (1992) and recently confirmed in a cross-cultural study as well (Silverman, Choi, & Peters, 2007). Moreover, gender differences in mental rotation processes can account for results in this condition. Mental rotation is generally considered to be involved in tasks requiring to compensate for the misalignment (e.g. Richardson, Montello, & Hegarty, 1999). This suggestion was compatible with our results when the target was located in the far side of landmark and the participants had to rotate 180° to realign their positions on respect to the target (e.g. Bosco et al., 2008).

4.3. Time and path length

The data confirmed a well-known effect in gender spatial navigation studies (e.g. Banta Lavenex & Lavenex, 2010; Astur, Tropp, Sava, Constable, & Markus, 2004; Picucci et al., 2010). Indeed, women covered more distance and spent more time to reach correctly the target and this effect remained unchanged a part from the spatial cues available. As in other studies (e.g. Moffat, Hampson, & Hatzipantelis, 1998; Astur et al., 2004), the experience with computer could not account for the observed behavioral differences in spatial navigation. Actually, reasons for the observed increased exploratory behavior by females are unclear. According to Mueller, Jackson, and Skelton (2008), these differences might arise from the ability of male to faster discriminate spatial cues. In our view, also affective factors such as lower spatial confidence can prolong women's decision processing. Nevertheless, in our task, gender differences did not emerged in the overall accuracy demonstrating that their prolonged exploratory behavior did not affect spatial achievement (e.g. Banta Lavenex & Lavenex, 2010).

4.4. Level of spatial confidence

Gender differences in spatial performance have been demonstrated to be affected by the level of self-confidence (e.g. Moè & Pazzaglia, 2006; Lawton & Kallai, 2002; Jeanne Sholl, Acacio, Makar, & Leon, 2000). This effect has been confirmed in the present study. In particular, a behavioral measure of levels of spatial confidence has been developed in the room containing only geometric information that are ambiguous, as suggested above (Bosco, Picucci, Caffò, & Lancioni, 2010; Miller & Shettleworth, 2007). The layout of the rectangular room without any distinctive landmark provided two equally correct solutions but only one, in fact, received a reward (shifting to the next trial). In our view, the lack of reward after "R" could discourage women, more skeptical about their spatial skills. Findings from the experiment support this claim. Men most often engaged in "RC" searching pattern showing to be confident in their spatial representation. A comparable result was found assessing the level of spatial confidence by mean of the self-report measure. In particular, women judge their confidence with spatial orientation ability poorer than men did. These results confirm literature showing higher level of spatial confidence in men rather than in women (O'Laughlin & Brubaker, 1998). Women seem to be less trusting in the encoding of geometry showing a more confused pattern of search. These findings are compatible with those by Cooke-Simpson and Voyer (2007) in an MRT task. The authors found that when women stated to be unconfident in their response accuracy, they fell in a guessing behavior. Our method of assessing spatial confidence might seem overlapped to the corresponding measure of accuracy. However, the low degree of correlation between accuracy and spatial confidence could suggest that accuracy and confidence of participants about their ability to reorient themselves are fairly independent (see also Busey et al., 2000; Chua et al., 2006). Behavioral and self-reported measure of self confidence showed a significant correlation demonstrating a relatively large overlapping between these two measures.

4.5. Spatial strategies

Spatial strategies adopted by men and women to cope with the task have been assessed taking into account the response patterns of the first and second searches, if the first was wrong. It was considered as a marker a coherent strategy only those patterns that turned to the correct corner after an error. Patterns presenting a sequence of incorrect corner were coded as the *guessing strategy*. As mentioned in the method section, two kinds of coherent spatial strategies could emerge in the rectangular rooms: *landmark and geometry-guided strategies*. Nonetheless, nobody of the participants showed to adopt the latter one. This outcome confirmed that geometry does not necessary dominates over landmark during reorientation (e.g. Ratliff & Newcombe, 2008; Picucci & Bosco, 2006) especially because geometry is considered as an ambiguous information in rectangular enclosures (e.g. Doeller, King, & Burgess, 2008). Landau and Lakusta (2009), in addition, recently suggested that within simple environments, navigation is primarily supported by cues that are easy to verbalize like typical landmarks. The straightforwardness of our landmark (i.e. a blue wall) and the simultaneous ambiguity of layout might have facilitated the access to a landmark-guided strategy. Besides this general effect, male and female did not exhibit differences in the selection of spatial strategies for both rectangular and square rooms, where landmark was near to the target. A possible explanation is that, in these conditions, the participants showed a, somewhat expected, ceiling-effect (ranging from 94% to 97%). On the other hand, women clearly adopted a landmark-guided strategy when the landmark and the target were on the opposite sides of the rectangular room. In the square room women were unexpectedly engaged in a guessing strategy more then men. Some considerations might clarify these findings. In our task participants could move within a circular arena having the same radius in both rectangular and square environments. The distance between landmark and the viewers in the former environment was greater in average than in the latter one. Learmonth et al. (2008) demonstrated that the strength of landmark attractiveness can vary as effect of its distance from the viewers. Gallistel (1990) also suggested that distant landmark guide navigation more precisely than a nearer one since it is perceived to be more stable as movement occurs. The stability of landmark is particularly crucial for women (e.g. Castelli, Corazzini, & Germinari, 2008; Cazzato et al., 2010; Ruggiero et al., 2008). Consequently, it is possible that landmark would attract women mainly when it is perceived as a stable benchmark, reducing otherwise its impact on spatial navigation when it is not perceived as completely safe for reorientation. If landmark loses its salience, women might become confused engaging in a guessing behavior. One can argue that guessing behavior might be well explained by the level of general self confidence about spatial orientation but this hypothesis cannot be entirely supported by data in the present study. In fact, the correlations between self confidence and the measures of guessing behavior are relatively low.

5. Conclusion

Considering the results of the present study, there is the need to revisit the way to look at reorientation paradigm data in a gender difference studies perspective. Important factors, such as level of spatial confidence and strategies, would remain veiled if only accuracy is assessed. In this view, the present study offers some new arguments for gender differences debate. First of all, a new assessment method to score the data has been proposed. Measures of spatial confidence and strategies have been obtained by a response pattern analysis thus providing a more reliable assessment of gender differences in this task. In our knowledge, this study represents the first attempt to evaluate spatial confidence by means of a behavioral measure and to definitely distinguish between a clear spatial – landmark or geometric – strategy and a guessing behavior. The suggested assessment method might contribute to disclose this kind of subtle gender differences. Second, as a general advice, this study suggests to control for fairness of the measures adopted in order to ensure the task to be gender-bias free and to avoid misleading conclusions about the differences between men and women. Therefore, findings from the present study appear consistent with an adaptive-combination model of spatial learning (e.g. Ratliff & Newcombe, 2008). Moreover, they suggest that the likelihood of using spatial information varies depending on the interaction of gender and environmental factors. More precisely, the ambiguity of spatial layout as well as the stability/salience of landmarks plays a role in the way men and women cope with the task. As a matter of fact, women handle geometric information as well as men; but the former appear to be less confident than men as effect of the ambiguity of the spatial cues. Furthermore, the performance of women is more accurate and coherent (in terms of adopted spatial strategies) if the landmark is near to the target and far from the viewer.

In conclusion, in very basic spatial orientation tasks that do not require fast or fine-grained (i.e. coordinate) responses, gender differences are very slight in accuracy, but they might appear in terms of spatial confidence and strategies. Overall, it is possible to argue that women have a lower tolerance to uncertainty about spatial information and that they are more constrained than men by the arrangement of the spatial cues.

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