Gender-based navigation stereotype improves men's search for a hidden goal

Abstract

While a general stereotype exists that men are better at navigating than women, experimental evidence indicates that men and women differ in their use of spatial strategies, and this preference determines gender-differences. When both environmental geometry and landmark cues are available, men appear to learn to navigate using both types of cues, while women show a preference for using landmarks. Using a computer-generated task, 80 undergraduate students from North-East England learned to navigate to a hidden goal. Activating the general navigation stereotype improved the performance of men, compared to the control condition, both when only geometric cues and only landmark cues were present (stereotype lift), suggesting that activating a general stereotype can affect tasks both with (geometry) and without (landmark) established gender-differences in preference. In addition, in the test trial (hidden goal removed) women who learned to navigate using only landmarks spent longer in the correct location of the hidden goal than those who learned to navigate using only geometry. In contrast, the opposite result was found for men, suggesting that when only one cue-type is available, gender-differences still occur, with women better able to navigate using landmarks than geometry, while men seemed to learn more about the location of the goal with reference to geometric than landmark cues.

Key words:

Learning; Navigation; Gender differences; Stereotypes; Stereotype lift

Introduction

There appears to be a general stereotype in many countries (e.g., USA: Harris, 1981; UK: Alleyne, 2009; Germany: Hausmann, Schoofs, Rosenthal, & Jordan, 2009) that men are better at navigating than women, while evidence from the navigation literature highlights that men and women are equally able to use landmark cues to navigate (US students: Saucier, Green, Leason, MacFadden, Bell, & Elias, 2002). However, gender-differences are apparent in navigation based on geometric cues, with men showing an advantage compared with women (US students: Sandstrom, Kaufman, & Huettel, 1998). One possible explanation for this finding is that men and women differ in their use of spatial strategies, and that this preference determines gender-differences in performance (Sandstrom et al., 1998). The discrepancy between the general navigation stereotype and genuine gender-differences in cue use offers an important opportunity to explore the role of actual specific gender-differences within a context of a broad gender stereotype. In addition, we extended the findings of previous studies to test participants with only geometric cues or only landmark cues, to explore whether the gender-difference in the use of geometric cues remains when only geometric cues are available for navigation, or whether women are able to adopt a geometric strategy in the absence of landmarks. It is also worth noting that this study complements other research published in *Sex Roles*, such as research examining how stereotypes can affect women's performance in STEM subjects (Shapiro & Williams, 2012), changing stereotypes with regard to gender stereotypes and academic ability (French children: Martinot, Bagès, & Désert, 2012), and differences between the genders in terms of navigational cues given in directions (US adults: Lawton, 2001).

In the UK (the cultural context of our study) a stereotype exists that men are superior to women in navigational ability. This has been shown in newspaper articles (Alleyne, 2009; Hill, 2010; Narain, 2010), magazines ("Tuesday's Big Issue: Stereotypes", 2009), and TV /

radio shows (Walton, 2012) which discuss the accuracy of this stereotype. Whilst knowledge of the stereotype seems ubiquitous from cultural (e.g., media) references, there appears to be little scientific research in the UK establishing the existence of this stereotype. Likewise, much of the research examining gender-differences in navigation tends to be carried out elsewhere (see below). However, we believe that these studies are still relevant to the UK, as their focus is gender-differences without emphasis on the cultural context of stereotypes.

Data from studies examining gender-differences in navigation initially appear to support the UK stereotype. In pencil-and-paper (US undergraduates: Galea & Kimura, 1993) and photograph-based tasks (US undergraduates: Holding & Holding, 1989) men make fewer errors than women when learning the route to a target location. This male advantage is also apparent in computer-based navigation tasks, in which a higher level of accuracy is achieved more quickly by men than by women on learning the location of an exit in a virtual complex maze (US students: Moffat, Hampson, & Hatzipantelis, 1998). However, a reliable and important finding from this research is that the genders use information from visual cues in distinctly different ways. Saucier et al. (2002) tested US college students' ability to navigate to a distant location by making use of either landmark- or Euclidean-based instructions. While men were equally quick to find their way to the goal using either method, women showed a distinct advantage when they were instructed to navigate by following landmarks than when they were to use distances and cardinal directions. Lawton (2001) found similar results when she asked US respondents to provide directions to a distant goal. Men referred more to cardinal directions while women referred more to landmarks. Navigation in computer-generated tasks also produces gender differences. A male advantage in time taken to locate a hidden (invisible) goal in such tasks by US college students has been hypothesized to be the result of men and women using different navigational methods (Astur, Tropp, Sava, Constable, & Markus, 2004). Sandstrom et al. (1998) found a similar pattern when men and women from a US university were trained in a virtual water maze to navigate to an invisible submerged platform. The platform's position could be determined by reference to the shape of the room (geometric cues) in which the water maze was located, and/or by reference to landmarks located inside the room. At test, when room shape was altered and only the landmarks indicated the platform's position within the virtual water, women and men found the platform equally quickly. However, when landmarks (objects inside the room) were removed (or moved randomly between test trials) and only room shape indicated the position of the platform, men found the platform quicker than women. Sandstrom et al. (1998) interpreted their findings as evidence that while both men and women use landmarks, men are able to adjust their strategy to use geometric information when landmark information is missing or unreliable. Taken together, these results, and others, suggest that men use Euclidean coordinates (US university students: Dabbs, Chang, Strong, & Milun, 1998; French adults: Lambrey & Berthoz, 2007), environmental geometry (Sandstrom et al., 1998; Canadian university students: Kelly & Bischof, 2005), and absolute distances (Dabbs et al., 1998; Dutch university students: Postma, Jager, Kessels, Koppeschaar, & van Honk, 2004) as well as landmarks to navigate, while women rely more primarily on landmarks (e.g., Kelly & Bischof, 2005; Lawton, 1994; US university students: Levy, Astur, & Frick, 2005). These differences are reflected not only when cues are removed or moved between trials, but also in eye movements directed to landmarks in a virtual maze (Canadian university students: Andersen, Dahmani, Konishi, & Bohbot, 2012).

One possible reason for the difference between men and women in spatial cue use is a difference in the reliance on distinct spatial strategies. Navigation based on a response strategy, which involves learning a sequence of body movements with reference to some stimulus, such as a reliable start position, or a distinctive feature of the environment, is thought to be dependent on the activity of the caudate nucleus (Canadian adults/patients:

Bohbot, Iaria, & Petrides, 2004; UK adults: Hartley, Maguire, Spiers, & Burgess, 2003; Canadian adults: Iaria, Petrides, Dagher, Pike, & Bohbot, 2003). Conversely, what might be termed a geometric strategy is thought to depend on the formation of a cognitive map of the environment, in which the geometric relations among multiple landmarks and surfaces in the environment are used to identify the person's position within their familiar environment. Functional neuroimaging studies have corresponded with animal studies showing the importance of the hippocampus in this kind of navigation (Bohbot et al., 2004; Hartley et al., 2003; Iaria et al., 2003; UK adults: Maguire, Spiers, Good, Hartley, Frackowiak, & Burgess, 2003). While Doeller, King, and Burgess (2008) found evidence for UK male adults that learning the locations of objects with reference to a nearby landmark was associated with activity in the caudate putamen, consistent (though not explicitly tested or stated by Doeller et al., 2008) with the possibility that men and women differ in their use of these strategies, others have found that men and women use spatial and response strategies equally (Bohbot et al., 2004; Iaria et al., 2003; Levy et al., 2005).

Jacobs and Schenk (2003) have proposed instead that reliance on different cue types reflects parallel cognitive map processes reflecting reliance on distal geometric cues as part of a directional system, while proximal landmarks are part of a positional system. Some behavioral data in humans (e.g., US undergraduates: Chai & Jacobs, 2009) and neurobiological studies in animals (Kemp & Manahan-Vaughan, 2008; Poirier, Amin, & Aggleton, 2008; Goodrich-Hunsaker, Hunsaker, & Kesner, 2008; Save, Paz-Villagran, Alexinsky, & Poucet, 2005) support such a view, although as yet no neurobiological data exist that dissociate cognitive maps based on proximal landmarks from those based on distal cues in humans. Thus the cognitive and associated neural processes thought to underlie differences in cue use in men and women are still under investigation.

The evolutionary origins of gender differences in human spatial abilities are also a matter of debate (reviewed in Jones, Braithwaite, & Healy, 2003). Hypotheses based on various evolutionary scenarios include differences in home range size (Ecuyer-Dab & Robert, 2004), foraging strategies (Eals & Silverman, 1994), and sexual selection (e.g., Geary, 1995; Sherry, 1997), and have all found favor in the literature. In terms of proximal causes of gender differences, mid-range levels of testosterone seems associated with optimal spatial performance in men (e.g., Dutch adults: van Goozen, Cohen-Kettenis, Gooren, Frijda, & van de Poll, 1995) while high levels of estrogen in women are associated with poorer spatial performance (e.g., German university students: Hausmann, Slabbekoorn, van Goozen, Cohen- Kettenis, & Güntürkün, 2000). Similar sex differences are found in many non-human mammalian species (e.g., Williams, Barnett, & Meck, 1990) and can be explained through similar evolutionary pressures as those put forward to explain gender differences in humans (Jones et al., 2003).

Whatever the biological determinants of spatial abilities, it is interesting to note that, as far as we are aware, researchers so far have not examined cultural or social factors that could affect gender differences in terms of navigation. That is, the role that the UK stereotype of men’s superior navigational abilities may have on men and women’s performance on a navigation task. Despite gender-differences in preference for cue use in navigation, little research has been carried out to examine whether these cue preference differences are represented in stereotypes surrounding gender and navigation. Hausmann, et al. (2009) went some way to address this, by measuring explicit stereotypes using a task similar to that employed by Halpern and Tan (2001). German students rated the probability a person they had never met before was male or female based on a behavioral description. Of the 16 items, four related to gender stereotypes surrounding navigation. Specifically, Hausmann et al. (2009) established that an individual is more likely to be perceived to be male if they can *draw a map of the area where he/she lives*. In addition, if they are *bad at reading street maps*, the individual is more likely to be perceived as female (but only by female participants). The third relevant item, that the individual *does not use landmarks for orientation*, is seen as not typically associated with being male or female. The final item, that the individual *remembers the way based on left-right turnoffs*, is seen to indicate that the individual is more likely to be male.

Together, these four items suggest that there is a stereotype that men are better at navigating than women; however, examining the specific items highlights a discrepancy with regard to stereotypes surrounding navigation and actual gender-differences in navigational strategy. Drawing (item 1) and reading (item 2) a map can be perceived as relating to a strategy of using geometric relations among stimuli, and as such the perception that men would be better able to carry out these tasks can be seen as reflecting actual gender-differences (although only women perceived men to be better able to read maps). In terms of the ability to use landmarks (item 3) the lack of a perceived difference between men and women also reflects the findings in the literature that both men and women can use a landmark strategy. Where the discrepancy lies between navigation-based stereotypes and actual gender-differences in cue use appears to lie with the ability to remember a route based on left-right turn-offs (item 4). This item appears to relate to the type of landmark cues described in Saucier et al.'s (2002) study. However, this description was perceived to be more likely to be a *male* behavior. Therefore, evidence from Hausmann et al. (2009) appears to suggest that there is a general perception that men are better at navigation than women (i.e., across the four items). However, when assessing the specific gender-differences with regards to cue use, perceptions are less well-defined. As Hausmann et al. (2009) used German participants, it may be possible that the findings do not translate to perceptions in the UK. However, as the general stereotype is the same in Germany and the UK, we feel that these findings are both relevant and applicable.

The discrepancy between the navigation stereotype and genuine gender-differences in cue use offers an important opportunity to explore the role of actual specific gender-differences within a context of a broad gender stereotype. Evidence for the detrimental effects of stereotypes is now well established within social psychological research, with *stereotype threat* (US university students: Steele & Aronson, 1995) suggesting that individuals may underperform on tasks where their group is negatively stereotyped, due to fear of confirming the stereotype (US university students: Spencer, Steele, & Quinn, 1999). A proportion of the stereotype threat literature focuses on gender stereotypes with women underperforming on math tests (US university students: Brown & Josephs, 1999; UK university students: Rosenthal & Crisp, 2006), and engineering exams (Canadian university students: Bell, Spencer, Iserman, & Logel, 2003); while men underperform on social sensitivity (US university students: Koenig & Eagly, 2005) and affective tasks (French university students: Leyens, Désert, Croizet, & Darcis, 2000). Situations that induce underperformance for the negatively stereotyped group have also resulted in an improvement in performance for the comparison group. This *stereotype lift* (Walton & Cohen, 2003) generally exists as a trend, but some studies have established the effect as tangible (e.g., French university students: Croizet, Després, Gauzins, Huguet, Leyens, & Méot, 2004). Hausmann et al. (2009) established stereotype lift for men completing a mental rotation task, although no corresponding stereotype threat was found for women. Mental rotation and navigation both involve spatial ability, and performance on mental rotation and navigation tasks have been found to correlate (Galea & Kimura, 1993; Canadian university students: Silverman, Choi, Mackewn, Fisher, Moro, & Olshansky, 2000). As such, it seems plausible that stereotype lift effects found on mental rotation tasks would also be found on navigation tasks.

In line with the stereotype literature, activating the stereotype of gender and navigation should improve the performance of men (stereotype lift) and impair the performance of women (stereotype threat) on navigation tasks. Importantly, the literature would suggest performance on *any* navigation task would be affected by activating the navigation stereotype. However, as discussed, the navigation literature highlights a discrepancy between the general navigation stereotype and actual performance. Specifically, no gender-differences are evident on tasks that involve the use of landmarks (Sandstrom et al., 1998; Saucier et al., 2002), while gender-differences do appear to emerge on tasks involving the use of geometric cues (Sandstrom et al., 1998). Stereotype research generally examines areas in which differences between the groups have been found previously. Indeed, stereotype threat is conceptualized as an explanation for prior underperformance. (e.g., African American SAT performance: Steele & Aronson, 1995; Steele, 1997; women and SAT math performance: Spencer et al., 1999). Examining navigation allows us to explore a domain where a general gender stereotype exists, but where gender-differences are only observed when a geometric strategy is required. This allows us to test the effect of a general stereotype where no actual gender-differences prevail (use of landmarks) and where an actual gender-difference does prevail (use of geometry). This allows further exploration of whether stereotypes affect only tasks with actual group differences, or whether activation of the stereotype affects all relevant tasks (i.e., all navigation tasks) regardless of any actual group differences.

In the experiment reported here we presented men and women with either a landmark-based or geometry-based navigation task. In the landmark task the location of a hidden goal could be determined by reference to the identities and positions of objects inside an otherwise uniform room. In the geometry task there were no landmarks. Instead, the position of the goal had to be learned with reference to the lengths of the walls forming the room, and the angles subtended by them. Therefore, unlike previous studies (e.g., Sandstrom et al., 1998) we tested participants with only geometric cues or only landmark cues. Any gender differences in the participants' ability to utilize these cues for navigation would extend the generality of these previous studies, by exploring whether the gender-difference in the use of geometric cues remains when only geometric cues are available for navigation, or whether women are able to adopt a geometric strategy in the absence of landmarks. Performance was measured by recording the time taken to locate the hidden goal in a series of training trials, before a single test trial was presented in which, unbeknownst to the participants, the hidden goal was removed and the time searching near the goal and near other similar, but incorrect, locations was recorded over a 60 second period (see Chai & Jacobs, 2009; Redhead & Hamilton, 2007, 2009, for similar methods). Previous 2D memory experiments have found evidence for men to outperform women at remembering locations based on the relative positions of objects, while the genders are equally good at remembering objects based on their visual features (UK university students: Jones & Healy, 2006), so we hypothesized that navigation tasks based on geometric and landmark cues would reveal gender differences in performance. Additionally, and most importantly, we hypothesized that stereotype activation would affect men's and women's navigation performance in the two navigation tasks, exploring whether stereotype activation affects performance regardless of the type of task, in line with the stereotype literature, or whether stereotype activation would affect performance only in the geometry task, which requires a strategy in which gender-differences have previously been revealed.

With respect to stereotype activation (Hypothesis 1) we predicted, regardless of navigation task, that the performance on the test trial and training trials of women in the control condition would be superior to that of women in the stereotype activation condition. This would be shown through poorer discrimination of corners (test trial) and slower learning of the location of the goal (training trials) in the stereotype activation condition compared to the control condition. Such findings would be in line with stereotype threat. Conversely, we predicted that activation of a navigation stereotype would improve men's performance on the test trial and training trials in both navigation tasks compared with their performance in the control condition, in line with stereotype lift. With respect to navigation based on landmarks and geometry (Hypothesis 2) we predicted, regardless of condition (stereotype activation / control), that women's performance on the test trial and training trials would be superior in the landmark than in the geometry task, but that men would perform equally well in both. In addition, men's performance on the test trial and training trials would be superior to that of females in the geometry task but not in the landmark task. ANOVAs tested our predictions. To summarize, our hypotheses were:

1. Performance (test trial and training trials) of women in the control condition would be superior to that of women in the stereotype activation condition, while performance of men in the stereotype activation condition would be superior to that of men in the control condition.
2. Women's performance (test trial and training trials) would be superior in the landmark than in the geometry task, but that men would perform equally well in both. In addition, men's performance would be superior to that of females in the geometry task but not in the landmark task.

Method

Participants & Design

Eighty students (40 male; 40 female) were approached on a university campus and asked to take part in a psychology experiment. Those who were recruited were given one of two navigational tasks (geometry vs. landmark) and placed in one of two conditions (control vs. stereotype activation). There were 10 participants in each gender by condition by task cell. Participants were aged 18-26 ($M = 21.38$; $SD = 1.99$), and a gender x condition x task ANOVA revealed no significant main effects or interactions for age, all $ps > .05$, suggesting no differences in sample distributions across cells.

Procedure

Participants were informed through written and verbal instructions that they would be using a computer-based navigation task to locate a hidden goal as quickly as possible, using the keyboard. They were informed that if the goal was not located within 60 seconds it would become visible and that they should head towards it. While participants in the control condition received no further information, those in the stereotype activation condition received additional written and verbal instruction stating “additionally, the results will be used to investigate any gender differences, therefore your performance will be compared to men / women [opposite gender]” (for similar instructions see Johns, Schmader, & Martens, 2005; Keller, 2007; Keller & Dauenheimer, 2003). Therefore participants received the control / stereotype activation instructions prior to training.

Virtual Navigation Tasks

We trained participants in one of two virtual environments that were programmed using the MAVERIK virtual reality system (Advanced Interfaces Group, 2008). The geometry task consisted of a regular trapezoid arena with no landmarks present. The landmark task consisted of a square-shaped arena with three distinctive landmarks (3D shapes: green cuboid, blue cube, yellow cylinder). From a first-person perspective, participants were required to navigate to a hidden goal, 0.3 m in diameter, located in same part of the arena on every training trial with respect to the arena’s shape (geometry task) or landmarks (landmark task). Assuming eye level to be 1.6 m, the walls of the arenas were 2 m high. With movement within the arenas programmed at 2 m/s, the subjective wall lengths were 4, 12, 10, and 10m in the trapezoid arena, and 10 m in the square arena.

Performance on the training trials was determined by recording the time taken to locate the hidden goal. If the goal was not located within 60 seconds it became visible as a tall red column and participants were required to navigate to it. On location of the goal, the participant was able to rotate on the spot but not to move forwards or backwards. After being held in this position for 5 seconds the next trial began automatically. There were 12 training trials with participants beginning each trial at the mid-point of one of the four walls, facing the wall. Start positions were in a pre-determined order such that each position was used once in every block of four trials (three blocks of four trials), with trial order varying between blocks. Following training, participants immediately received the test trial. Participants were not informed that the final trial was different from the preceding trials. Unlike in the training trials, no goal was present in the test trial, and the start position was the center of the arena. The test trial lasted for 60 seconds, with search activity recorded as the time spent in the correct corner location – a zone 1.6 m in diameter, centered on the goal's previous position. Search activity in 1.6 m diameter zones in equivalent positions in the other corners of the arena were also recorded to ensure that participants were able to discriminate the correct corner from similarly placed, but incorrect, corners. Any differences between conditions or genders could not then be explained by more intense searching in any corner. It should be noted for comparison between tasks that the interzone distances were different for the trapezoid (geometry) and square (landmark) arenas.

Demographic Information

In order to establish knowledge of the stereotype, participants were asked to state who they felt would perform better on the task they had just completed, with the choice of *men*, *women*, or *equal*. Age and gender were also recorded.

Results

Stereotype knowledge

Three participants stated that they expected women to perform better on the task than men (range across gender, condition, and task). In order to ensure knowledge of the stereotype was equivalent across participants, these participants were removed from the main analyses. Participants who thought the genders would perform equally were retained, due to the possibility that they may be conforming to social desirability effects (i.e., stating what they thought the experimenter wanted them to state), which is distinct from explicitly stating counter-stereotypical views (i.e., women are better than men). In line with the stereotype, more of the remaining participants expected men to perform better (n = 48), than for the genders to perform equally (n = 29), χ^2 (1) = 4.69, p = .030. This observation was not contingent on participant gender, χ^2 (1) = 0.11, p = .746, condition, χ^2 (1) = 0.38, p = .537, or navigation task, χ^2 (1) = 0.11, p = .746. This suggests that knowledge of the stereotype was equivalent across the remaining participants, regardless of their gender, the condition to which they were assigned, or interestingly, the navigation task on which they were tested. This lends further support to the idea that there is a general navigation stereotype in favor of men, which is not specific to actual gender-differences in strategy.

Descriptives

Table 1 contains all means and SDs for women and men within each condition and task for the time spent in the correct corner and three incorrect corners for the test trial of the navigation task. Table 2 contains all means and SDs for women and men within each condition and task for the time taken to find the goal in each block of the training trials (three blocks of four trials) of the navigation task. We discuss these descriptives with reference to our hypotheses and analysis below.

Test trial

To determine the extent to which participants learned the location of the goal with reference to the landmark and geometric cues (Hypothesis 2) provided in the two navigation tasks, and the effect of stereotype activation on spatial performance (Hypothesis 1), the time spent in the corner zone of the test trial, where the goal had been located during training, (correct corner) was compared with time spent in zones in the equivalent locations in the other corners of the arenas (incorrect corners 1, 2, & 3). Comparisons of times spent in the incorrect corners between tasks should be treated with caution as the locations of incorrect corners 1, 2, and 3 were different between the landmark and geometry tasks, due to the differing shape of the arenas.

A mixed ANOVA of time in each corner (correct; incorrect 1; incorrect 2; incorrect 3), with gender (male; female), condition (control; stereotype activation), and task (landmark; geometry) as between-subjects variables, revealed a significant main effect of corner, F (3, 207) = 47.52, p < .001, η_p^2 = .408, with pairwise comparisons (Bonferroni adjusted) revealing that more time was spent in the correct corner (M = 10.50 ; SD = 7.86) than in the incorrect corners (incorrect 1: M = 3.78; SD = 2.44; p <.001; incorrect 2: M = 2.99; SD = 2.46; p <.001; incorrect 3: M = 3.19; SD = 2.31; p <.001). There was also a main effect of condition, F (1, 69) = 6.48, p = .013, η_p^2 = .086, task, F (1, 69) = 7.30, p = .009, η_p^2 = .096, and a condition x task interaction, F (1, 69) = 5.47, p = .022, η_p^2 = .073. Importantly, in line with Hypothesis 1, there was a significant three-way corner x gender x condition interaction, F (3, 207) = 3.74, p = .012, η_p^2 = .051, and in line with Hypothesis 2, there was a significant corner x gender x task interaction, F (3, 207) = 7.30, p < .001, η_p^2 = .102. All other main effects and interactions were non-significant.

Hypothesis 1

We first explored the corner x gender x condition interaction in order to examine the extent to which the location of the goal had been learned for men and women in each condition. Figure 1 shows the mean times spent in each of the four corners for both genders in the stereotype activation and control conditions. Pairwise comparisons (Bonferroni adjusted) were used to determine whether women in the two conditions discriminated between the correct corner and the incorrect corners (i.e., learned the correct location of the goal). Women in the control condition spent significantly longer in the correct corner (M =

10.43; *SD* = 9.85) compared to incorrect corner 1 (*M* = 3.13; *SD* = 2.45), *p* = .002, incorrect corner 2 (*M* = 2.51; *SD* = 2.20), *p* < .001, and incorrect corner 3 (*M* = 3.42; *SD* =2.54), *p* = .003. In the stereotype activation condition women spent significantly longer in the correct corner (*M* = 9.86; *SD* = 6.27) compared to incorrect corner 1(*M* = 3.54; *SD* = 2.86), *p* = .018, and incorrect corner 3 (*M* = 3.46; *SD* = 3.06), *p* = .015, and marginally significantly longer compared to incorrect corner 2 (*M* = 4.21; *SD* = 3.06), *p* = .052. This suggests that women in both the control and stereotype activation conditions were able to discriminate between the correct location of the goal, and the incorrect locations.

Similar pairwise comparisons (Bonferroni adjusted) established that for men in the control condition, although the means were in the predicted direction, there was no significant difference between time spent in the correct corner (*M* = 7.74; *SD* = 6.78) compared with incorrect corner 1 (*M* = 3.98; *SD* = 2.00), *p* = .355, incorrect corner 2 (*M* = 3.32; *SD* = 2.36), *p* = .185, or incorrect corner 3 (*M* = 3.01; *SD* = 1.70), *p* = .114. In contrast, men in the stereotype activation condition spent significantly longer in the correct corner (*M* = 13.78; *SD* = 7.19) compared with incorrect corner 1 (*M* = 4.44; *SD* = 2.39), *p* < .001, incorrect corner 2 (*M* = 2.06; *SD* = 1.73), *p* < .001, and incorrect corner 3 (*M* = 2.88; *SD* = 1.86), *p* < .001. This is evidence that men in the stereotype activation condition were able to discriminate the correct location of the goal from other similar locations. The finding for the control condition is intriguing, with possible explanations for this finding explored in the General Discussion.

We next examined the extent to which participants spent time in the correct corner in the control condition compared to the stereotype activation condition. Simple main effects (Bonferroni adjusted) revealed no significant difference between the amount of time spent in the correct corner for women in the stereotype activation condition compared to women in the control condition, F (1, 69) = 0.06, p = .813, $\eta_p^2 < .001$. This suggests that there was no evidence for stereotype threat, with no evidence that women spent less time in the correct corner in the stereotype activation condition than the control condition. However, in line with stereotype lift, simple main effects (Bonferroni adjusted) revealed that men in the stereotype activation condition spent more time in the correct corner than those in the control condition, F (1, 69) = 6.30, p = .014, η_p^2 = .084.

Hypothesis 2

We next explored the significant corner x gender x task interaction in order to test Hypothesis 2. The performance of men and women in the test trials for the landmark and geometry tasks is shown in Figure 2. Pairwise comparisons (Bonferroni adjusted) revealed that women completing the landmark task were able to discriminate among corners in the test trial, with a significant difference between time spent in the correct corner (*M* = 12.67; *SD* = 8.64), and incorrect corner 1 (*M* = 2.85; *SD* = 2.17), $p < .001$, incorrect corner 2 (*M* = 2.08; *SD* = 1.93), $p < .001$, and incorrect corner 3 (*M* = 2.15; *SD* = 1.75), $p < .001$. On the other hand, women completing the geometry task did not spend significantly more time in the correct corner than in the other corners, with no significant difference between the correct corner (*M* = 7.66; *SD* = 7.21) and incorrect corner 1 (*M* = 3.81; *SD* = 3.00), p = .385, incorrect corner 2 (*M* = 4.55; *SD* = 2.92), p = .810, and incorrect corner 3 (*M* = 4.72; *SD* = 3.01). p = .848, This suggests that women learned the location of the goal in the landmark task, but not in the geometry task.

Pairwise comparisons (Bonferroni adjusted) revealed that men completing the geometry task successfully discriminated the correct corner (*M* = 13.45; *SD* = 7.97) from incorrect corner 1 (*M* = 4.30; *SD* = 2.50), $p < .001$, incorrect corner 2 (*M* = 2.93; *SD* = 2.32), $p < .001$, and incorrect corner 3 (*M* = 3.00; *SD* = 1.99), $p < .001$. For men completing the landmark task there was no significant difference between time spent in the correct corner (*M* = 8.35; *SD* = 6.36) and time spent in incorrect corner 1 (*M* = 4.14; *SD* = 1.92), p = .206, although they did spend more time in the correct corner than either incorrect corner 2 (*M* = 2.42; *SD* = 1.97), *p* = .023, or incorrect corner 3 (*M* = 2.89; *SD* = 1.56), *p* = .038. This suggests that men were able to correctly discriminate the correct from incorrect corners for both tasks, although the non-significant difference between the time spent in the correct corner and one of the incorrect corners in the landmark task may be an indication that men are better at the geometry task than the landmark task.

To explore any differences between tasks (i.e., Hypothesis 2) we next examined whether women spent more time in the correct corner of the landmark arena than the correct corner of the geometry arena. Simple effects (Bonferroni adjusted) revealed that this proposition was supported, with women spending more time in the correct corner in the landmark test than in the geometry test, F (1, 69) = 4.16, p = .045, η_p^2 = .057. In contrast with our prediction that men would perform equally well in both tasks, men spent significantly more time in the correct corner during the geometry test trial than in the landmark test, F (1, 69) = 4.26, p = .043, η_p^2 = .058.

We next examined the second part of Hypothesis 2 that there would be no difference between time spent in the correct corner by men and women in the landmark task, but that men would spend more time in the correct corner in the geometry task than women. Simple effects (Bonferroni adjusted) revealed that in the landmark task women spent marginally more time in the correct corner than men, F (1, 69) = 3.20, p = .078, η_p^2 = .044. However, men spent significantly more time than women in the correct corner during the geometry test trial, F (1, 69) = 5.34, p = .024, η_p^2 = .072. This is in line with our predictions, and is in line with the literature proposing equal performance between the genders in landmark-based navigation.

Training trials

The training trial data were analyzed in order to further examine the extent to which stereotype activation (Hypothesis 1) and task (Hypothesis 2) affected performance. Figure 3 shows the time (seconds) taken to locate the hidden goal during training trials. A gender x condition x task x block (three blocks of four trials) ANOVA, with repeated measures on the final factor, revealed a main effect of block, $F(2,138) = 26.18$, $p < .001$, $\eta_p^2 = .275$. Pairwise comparisons (Bonferroni adjusted) revealed that the goal was located quicker in the second block ($M = 22.67$, $SD = 14.08$) compared to the first ($M = 29.64$, $SD = 13.51$), $p < .001$, and quicker in the third block ($M = 18.95$, $SD = 13.38$) compared to the second, $p = .021$. There was a main effect of gender, $F(1,69) = 10.29$, $p = .002$, $\eta_p^2 = .130$. Across trials men ($M = 19.93$; $SD = 11.16$) found the goal quicker than women ($M = 27.68$; $SD = 9.97$). The block x condition interaction was significant, $F(2,138) = 4.78$, $p = .010$, $\eta_p^2 = .065$, with simple effects (Bonferroni adjusted) revealing no significant difference between the control ($M = 28.84$, $SD = 14.15$) and stereotype activation ($M = 30.46$, $SD = 12.96$) conditions in the first block, $F(1,69) = 0.39$, $p = .534$, and no significant difference between the control ($M = 24.72$, $SD = 14.37$) and stereotype activation condition ($M = 20.56$, $SD = 13.64$) in the second block, $F(1,69) = 1.49$, $p = .226$. However, in the third block participants in the stereotype activation condition ($M = 14.99$, $SD = 10.18$) were quicker to find the goal than participants in the control condition ($M = 22.81$, $SD = 15.04$), $F(1,69) = 7.08$, $p = .010$, $\eta_p^2 = .093$. All other main effects and two-way interactions were non-significant.

Hypothesis 1

The block x gender x condition interaction was non-significant, $F(2,138) = 0.56$, $p = .575$, $\eta_p^2 = .008$, which suggests that we cannot support Hypothesis 1 that women in the control condition would be quicker to learn the location of the goal than women in the stereotype activation condition, while men would be quicker to learn the location of the goal under stereotype activation. Instead, it appears as though (based on the significant block x task interaction above) both men and women learned the position of the goal quicker in the stereotype activation condition than the control condition. Considering the non-significant results on the test trial and therefore lack of support for Hypothesis 1 for women (no evidence of stereotype threat for women on the test trial), this finding here is perhaps not surprising.

Hypothesis 2

Of the three- and four-way interactions, only the block x gender x task interaction was significant, $F(2,138) = 3.14$, $p = .047$, $\eta_p^2 = .043$. This interaction relates to Hypothesis 2, that women would be quicker to learn the location of the goal in the landmark task than the geometry task, while men would show no difference between the two tasks. In order to examine this hypothesis, we first examined within-gender effects.

For women in the geometry condition, pairwise comparisons (Bonferroni adjusted) revealed no significant difference between the first block (*M* = 32.60; *SD* = 9.83) and the second block (*M* = 30.61, *SD* = 13.43), *p* = 1.00, the first and third blocks *(M* = 26.83; *SD* = 11.31), *p* = .255, or the second and third blocks, *p* = .472. This suggests that for women in the geometry condition performance did not change over time. In comparison, for women in the landmark condition, there was a significant difference between the first block (*M* = 33.51, *SD* = 15.35) and the second block (*M* = 22.37, *SD* = 12.92), $p < .001$, and the first block and third block (*M* = 20.13, *SD* = 12.50), $p < .001$, while there was no significant difference between the second block and the third block, *p* = 1.00. This suggests that women in the landmark condition successfully improved their performance over time.

Men in the geometry condition successfully improved their performance in terms of locating the goal, with a significant difference between the first block (*M* = 28.06; *SD* = 13.92) and the second block (*M* = 18.21; *SD* = 11.23), *p* = .005, and the first block and the third block (*M* = 13.99; *SD* = 9.92), $p < .001$, while there was no significant difference between the second block and third block, *p* = .385. This suggests that men, unlike women, were successfully able to learn the location of the goal in the geometry condition. In the landmark condition, there was no significant difference between the first block (*M* = 24.65, *SD* = 13.40) and the second block (*M* = 19.64, *SD* = 15.88), $p = .254$, or between the second block and third block (*M* = 15.06, *SD* = 15.79), $p = .279$, but there was a significant difference between the first block and the third block, $p = .016$, suggesting that men had improved their performance by the end of the trials.

We next explored the interaction between-gender. Simple effects (Bonferroni adjusted) revealed that for the first block of the landmark task, men located the goal quicker than women, $F(1,69) = 4.54$, $p = .037$, $\eta_p^2 = .062$. However, this male advantage was not apparent in the latter two blocks; with no significant difference between men and women on the second block, $F(1,69) = 0.42$, $p = .517$, or between men and women on the third block, $F(1,69) = 1.61$, $p = .209$.

For the first block of the geometry task, there was no significant difference between the performance of men and women, $F(1,69) = 1.10$, $p = .297$. However, for the second block men located the goal quicker than women, $F(1,69) = 7.79$, $p = .007$, $\eta_p^2 = .101$. Men also located the goal quicker than women in the third block, $F(1,69) = 10.03$, $p = .002$, $\eta_p^2 = .127$. This suggests that beyond the first block of trials men were quicker to learn the location of the goal in the geometry task than women.

Discussion

Our experiment had two hypotheses: (1) in terms of the effect of stereotype activation on navigation, we considered that the performance (test trial and training trials) of women in the control condition would be superior to that of women in the stereotype activation condition on both navigation tasks, in line with stereotype threat. Conversely, activation of a navigation stereotype would improve men's performance in both navigation tasks compared with their performance in the control condition, in line with stereotype lift; (2) with respect to navigation based on landmarks and geometry we predicted, regardless of condition (stereotype activation / control), that women's performance would be superior in the landmark than in the geometry task, but that men would perform equally well in both. In addition, men's performance would be superior to that of females in the geometry task but not in the landmark task.

In terms of the first hypothesis, the experiment established that when the navigation stereotype was activated men searched for longer in the correct location (test trial) compared to the control condition, in line with stereotype lift. This was the case for both the landmark- and geometry-based tasks and suggests that the general stereotype that men are better at navigating than women can affect performance both when there is a discrepancy (both women and men can use landmarks to navigate) and where there are actual gender-differences (women are better able to use landmarks than geometric cues, while men are equally able to use either).

Interestingly, while activation of the stereotype affected men, who spent longer in the correct location when the stereotype was activated compared to men in the control condition (stereotype lift), stereotype activation did not affect women's performance on the test trial. Finding a situation in which men's performance improves without the deterioration of women's performance (stereotype threat) demonstrates that activating stereotypes can have important positive consequences. The lack of a significant effect of stereotype activation for women was reflected not only on the test trial, but also in the training trial data, which showed that both men and women were quicker to locate the goal under stereotype activation. This finding is in line with the test trial results for men. One explanation for finding stereotype lift, but not stereotype threat, may lie with the tasks employed, which may not have been sensitive enough for us to detect a drop in performance. One aspect of stereotype threat is the finding that the task must be of sufficient difficulty to affect performance (Spencer et al. 1999), therefore it is possible that the tasks here were not of sufficient difficulty to produce stereotype threat. Alternatively, the opposite may be true, and the tasks may have been too difficult, with the results showing a floor-effect. Women taking the geometry task were unable to discriminate between the correct corner and the three incorrect corners in the test trial. This may indicate that the geometry task was too difficult, and that women completing this task were unable to successfully learn the location of the goal. This may indicate that examining stereotype activation for this task may be inappropriate as the task is too difficult to measure changes in performance based on stereotype activation.

A further possibility is that the stereotype activation condition did not simply activate a stereotype, but instead activated social comparisons or competition between groups, producing an increase in effort and thus performance in men. This could account for why stereotype lift, but not stereotype threat, was observed. Although this could be true of our experiment we feel it is unlikely, as stereotype threat effects have been found previously for men (e.g., social sensitivity: Koenig & Eagly, 2005). Therefore it is not the case that such situations always result in improved performance for men, suggesting that the stereotype itself is key to improved performance. However, stereotype research has not explicitly addressed this concern regarding competition, and may be an important area for future research.

Rather than focusing on the stereotype activation condition, another consideration may be the control condition. Our control condition consisted of giving participants no information about the task in terms of gender-differences, however, other researchers have included control conditions that directly reduce the effects of stereotypes on performance (for a review see Nguyen & Ryan, 2008). As such, one could argue that the control condition does not eliminate the possibility of stereotype activation, and therefore, that the stereotype may be activated in the control condition (albeit subtly). This may explain our lack of stereotype threat for women, as it may be that they are experiencing stereotype threat in both conditions, and that there is therefore no difference between the control and stereotype activation conditions.

Our results provide evidence for stereotype lift, but not stereotype threat. Similar effects have been shown in the motor domain (French undergraduate students: Chalabaev, Stone, Sarrazin, & Croizet, 2008), raising the possibility that susceptibility to stereotype lift effects, compared to stereotype threat effects, is stronger under certain conditions. Considering Walton and Cohen's (2003) assertion that stereotype lift effects tend to be smaller than stereotype threat effects our results appear to be at odds with those of their meta-analysis.

Perhaps the cause of this discrepancy lies in the potential moderators of stereotype lift. Researchers have noted a number of factors which may increase the likelihood of experiencing stereotype lift. Along with the biological predictor that high testosterone men were more likely to experience stereotype lift on a math test, compared to low testosterone men (US undergraduates: Josephs, Newman, Brown, & Beer, 2003), other moderators have focused on aspects of stereotype belief. For example, a belief that ability is fixed, compared to a belief that ability is malleable (US students: Mendoza-Denton, Khan, & Chan, 2008) has been found to result in stereotype lift, as has high social dominance orientation (Canadian undergraduates: Danso & Esses, 2001), and high stereotype endorsement (French high school students: Chatard, Selimbegovic, Konan, & Mugny, 2008). These findings suggest that beliefs relating to, and reinforcing, the stereotype may work to increase the likelihood of stereotype lift occurring. This notion is reinforced by the finding that those high in prejudice are more likely to experience stereotype lift (Chatard et al., 2008). This may suggest that the navigation stereotype may be particularly endorsed by men in the UK, which has resulted in the stereotype lift effects observed here.

With respect to the second hypothesis, it was found that women spent longer searching for the goal in the correct location of the test trial when they were trained on a landmark-based task than a geometry-based task. In contrast, men spent longer in the correct corner of the geometry task than the landmark task. However, there was no significant difference between men and women in the time spent searching in the correct corner of the arena during the landmark test trial, while men spent more time than women in the correct corner during the geometry test trial. Previous research established that when trained in an environment with both landmarks and geometric cues present, men and women differed in their ability to use geometric information (Sandstrom et al., 1998). However, in Sandstrom et al.'s study training included both geometry and landmark cue types and it appears as though women's strategy preference to learn the location of the platform using landmarks was detrimental to learning based on geometry cues. What the study was unable to assess was whether women differ in their ability to navigate with respect to landmark- and geometry-based information when only one of those cue types is available as a source of information. Although Saucier et al.'s (2002) study shows that men were quicker than women at navigating when given Euclidean instructions (which required an appreciation of the geometric relations among environmental cues and self-location with respect to those cues), our experiment more closely resembles Sandstrom et al.'s design, with the inclusion of a training stage and no fixed route to follow. Our experiment builds on these previous findings by establishing that men and women differ in their ability to use geometric and landmark cues when only one type of cue is available during training. Women are better able to navigate using landmarks than geometry, while men appear better able to use geometry than landmark cues. This latter finding is in contrast to our prediction that men would perform equally well in both navigation tasks.

Analysis of the results from the training trials might provide some insight into men and women's performance during the test trial. Men found the goal more quickly in the landmark task than did women, but only for the first block of trials. In contrast, there was no difference in time taken to find the goal in the first block of the geometry task, but men found the goal quicker than women in the second and third blocks. This, along with the test trial data, suggests that there is a gender-difference in the use of geometric cues, which is present even in the absence of landmarks (Sandstrom et al., 1998). It is possible that these between-gender differences reflect some inherent differences in the intensity or salience of landmark and geometric cues to men and women. In studies of Pavlovian conditioning, stimulus salience is thought to vary the extent to which a cue can enter into an association with an outcome (Hull, 1949) and as such more salient cues are learned about more quickly than those with lower salience (e.g., US undergraduates: Grice & Hunter, 1964) a finding which is incorporated into formal theories of associative learning (e.g., Rescorla & Wagner, 1972). Furthermore it is thought the salience of cues can be modified by natural selection (e.g., Kalat & Rozin, 1970), which, as stated in the introduction, is thought to have driven differences between men and women in cue use (Jones et al., 2003). Some support for this analysis can be found by examining the within-gender differences observed between tasks in our experiment. Men in the geometry task learned more rapidly than those in the landmark task, which may reflect the difference in salience between landmarks and geometry for men. That differences between landmark and geometry tasks have not been observed for men in the past may be the result of extended training in which learning eventually equates. Equally, the lower salience of geometric cues for women could result in poorer learning about the relationship between them and the location of the goal, resulting in the observed differences between landmark and geometry tasks. We would predict, based on the associative principles described above, that with extended training women in the geometry task would be just as quick as those in the landmark task, which would result in no differences during the test trials.

In combining the navigation and stereotype literatures, we have made a tentative step in clarifying the role of stereotypes on the learning process. Stereotype activation occurred before training took place, which indicates that stereotype activation can have a positive effect on learning. This was seen in the training trial data where participants under stereotype activation located the goal more quickly in the final block of trials than those in the control condition, although no difference between conditions was established in the first or second blocks. It is interesting that this effect occurred regardless of gender or navigation task, with participants who were made aware of the general navigation stereotype quicker to locate the goal in the final block of trials than participants in the control condition. This may suggest that activation of the stereotype results in quicker learning of the location of the goal. Although we expected to see this effect only for men, with the lack of stereotype threat results for women on the test trial, this result is not entirely surprising.

One possible future direction for research examining gender-differences in cue-based preference is to explore possible underlying mechanisms shared by navigation and stereotype threat / lift. Although due to limited research, little is known about the underlying mechanisms of stereotype lift, a number of underlying processes have been considered as the basis for stereotype threat, including decreased working memory (Schmader, Johns, & Forbes, 2008), prevention focus (US university students: Grimm, Markman, Maddox, & Baldwin, 2009), and performance expectancies (UK university students: Rosenthal, Crisp, & Suen, 2007). It is possible that geometric-based navigation relies on different underlying processes than landmark-based navigation, which map onto the different processes outlined as mechanisms underlying stereotype threat. Such examination would further enhance theoretical links between gender-differences in cue use and susceptibility to stereotypes.

To conclude, we have shown that women are better able to navigate when presented with a landmark-based task than a geometry-based task, while men's performance is consistent across tasks. In addition, activating the general navigation stereotype resulted in improved performance for men, compared to the control condition, regardless of navigation task. These findings suggest that women have a preference for a landmark strategy, and that men's performance can be improved by activating the general navigation stereotype.

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Table 1

Means (and SDs) for time (seconds) spent in each corner (correct, incorrect 1, incorrect 2, & incorrect 3) by gender, task, and condition

Gender	Condition	Task	Correct corner	Incorrect corner 1	Incorrect corner 2	Incorrect corner 3
Male	Control	Landmark	6.20	4.12	3.17	2.47
			(6.63)	(1.39)	(2.29)	(1.57)
		Geometry	9.45	3.83	3.49	3.61
			(6.92)	(2.61)	(2.57)	(1.71)
	Stereotype activation	Landmark	10.51	4.15	1.68	3.31
			(5.57)	(2.41)	(1.31)	(1.52)
		Geometry	17.05	4.73	2.43	2.45
			(7.37)	(2.46)	(2.08)	(2.14)
Female	Control	Landmark	13.97	3.36	1.59	2.32
			(11.24)	(2.51)	(2.11)	(1.71)
		Geometry	6.90	2.90	3.43	4.52
			(7.14)	(2.52)	(1.97)	(2.83)
	Stereotype activation	Landmark	11.23	2.27	2.62	1.96
			(4.62)	(1.69)	(1.66)	(1.87)
		Geometry	8.49	4.81	5.79	4.95
			(7.62)	(3.31)	(3.40)	(3.37)

Note. SDs are given in parentheses. Maximum time spent in each corner is 60 seconds

Table 2

Means (and SDs) for average time (seconds) taken to find the goal across trials in each block (block 1, block 2, & block 3) by gender, task, and condition

Gender	Condition	Task	Block 1	Block 2	Block 3
Male	Control	Landmark	26.27	25.25	21.59
			(17.59)	(18.42)	(19.13)
		Geometry	26.80	20.17	15.47
			(13.07)	(10.03)	(12.16)
	Stereotype	Landmark	23.03	14.02	8.54
	activation		(7.98)	(11.09)	(8.10)
		Geometry	29.19	16.45	12.66
			(15.25)	(12.48)	(7.83)
Female	Control	Landmark	28.75	20.97	22.21
			(13.87)	(12.55)	(13.25)
		Geometry	33.34	32.05	31.24
			(12.57)	(13.79)	(12.12)
	Stereotype	Landmark	38.80	23.93	17.81
	activation		(15.95)	(13.90)	(11.94)
		Geometry	31.77	29.02	21.93
			(6.17)	(13.65)	(8.45)

Note. SDs are given in parentheses. Maximum time for each block is 60 seconds

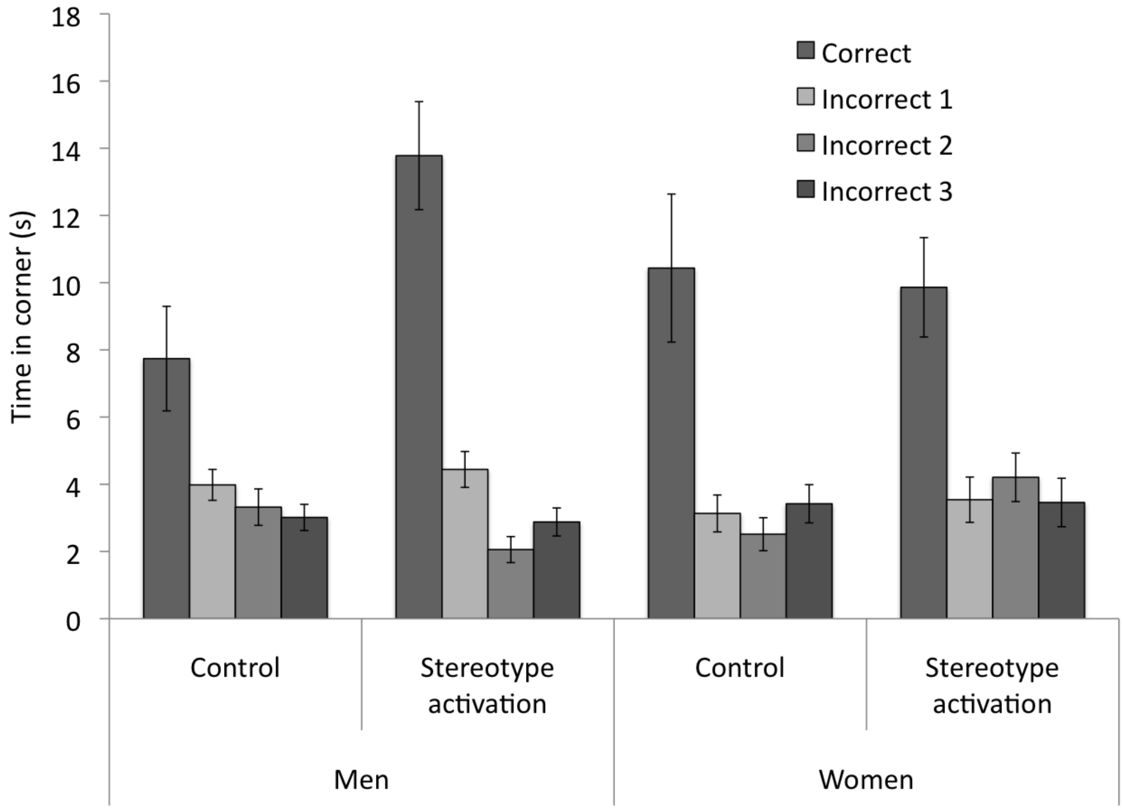
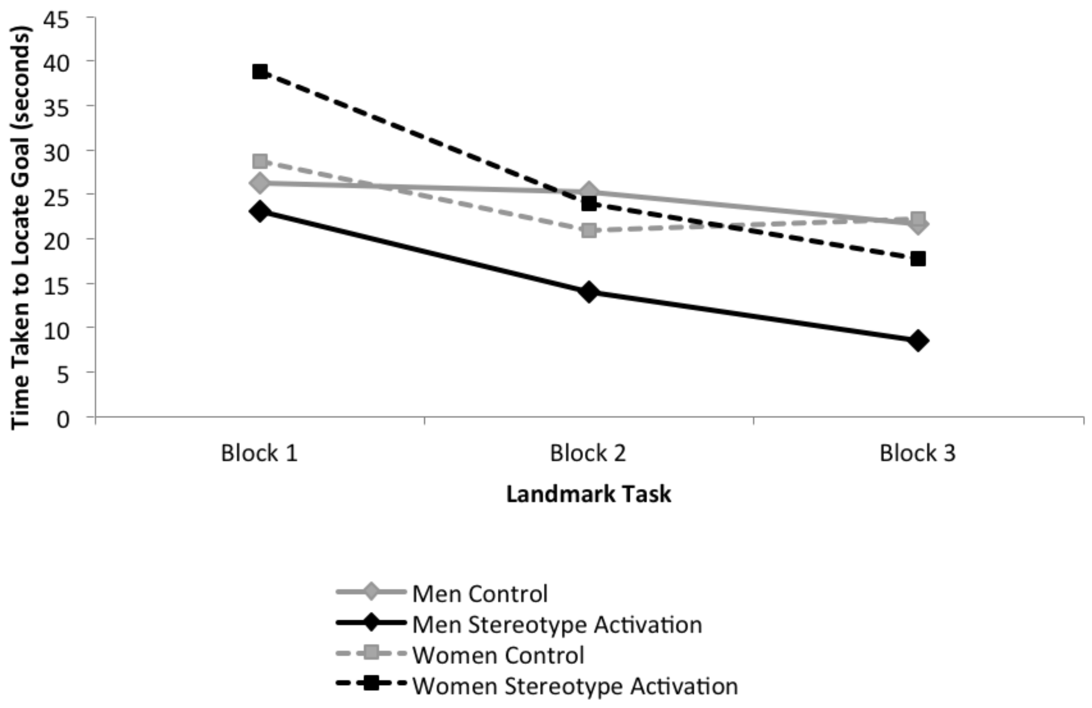


Figure 1. Means for time (seconds) spent in each corner (correct, incorrect 1, incorrect 2, & incorrect 3) by gender and condition. Correct refers to the top-right corner of the landmark (square)/geometry (trapezoid) arena; incorrect 1 refers to the bottom-left corner of the landmark/geometry arena; incorrect 2 refers to the top-left corner of the landmark/geometry arena; incorrect 3 refers to the bottom-right corner of the landmark/geometry arena.

Figure 2. Means for time (seconds) spent in each corner (correct, incorrect 1, incorrect 2, & incorrect 3) by gender and task. Correct refers to the top-right corner of the landmark (square)/geometry (trapezoid) arena; incorrect 1 refers to the bottom-left corner of the landmark/geometry arena; incorrect 2 refers to the top-left corner of the landmark/geometry arena; incorrect 3 refers to the bottom-right corner of the landmark/geometry arena.



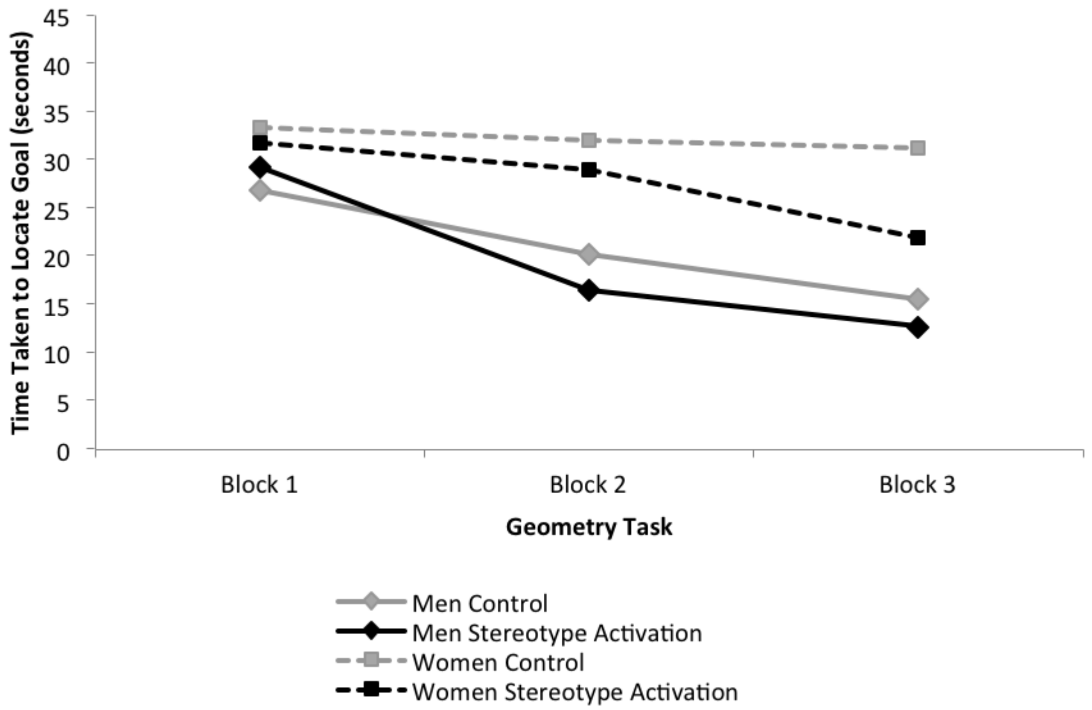


Figure 3. Time taken (in seconds) to locate the hidden goal, in the landmark task (top) and geometry task (bottom), during the training trials.