Current Psychology (2023) 42:4979–4990
https://doi.org/10.1007/s12144-021-01849-7

The effect of stereotype threat on females' spatial perspective taking and the mediating role of executive functions

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Accepted: 10 May 2021 / Published online: 17 May 2021

Abstract
Females are considered to be at a disadvantage in spatial perspective taking. In this study, we examined whether stereotype threat negatively affects females' spatial perspective-taking ability and executive functions. Then we explored which components of executive function play a mediating role in the effect of stereotype threat on females' spatial perspective-taking ability. We carried out two experiments. In Experiment 1, female participants in a stereotype threat condition or a control condition completed a spatial perspective-taking test. The results showed that females' spatial perspective-taking ability was reduced by stereotype threat. In Experiment 2, female participants were again assigned to a stereotype threat condition or a control condition; then they were asked to complete tasks measuring three executive functions (inhibition, shifting, and updating), following which they completed the spatial perspective-taking test. Experiment 2 found that stereotype threat decreased inhibition, updating, and spatial perspective-taking performance. The results also showed that only inhibition accounted for the effect of stereotype threat on spatial perspective taking. To sum up, the results from the current study shed new light on the relationship between stereotype threat and spatial perspective-taking ability and explained the relationship from a more detailed perspective.

Keywords Stereotype threat · Spatial perspective taking · Executive functions · Inhibition · Female

Introduction

Perspective taking is the cognitive ability to understand others' viewpoints, in other words "to put oneself into someone else's shoes", which includes spatial perspective taking and social perspective taking (Tarampi et al., 2016). Social perspective taking focuses on how people understand others' beliefs or mental states. Different from social perspective taking, spatial perspective taking refers to the ability to visualize objects from an imaginary observer's view at other points in space (Kessler & Wang, 2012). Spatial perspective taking includes two kinds of processes. The first process is to judge whether an object can be seen by following the sight of others. The second one is to judge an object's location relative to another object, which requires transforming orientation from one's egocentric perspective (Michelon & Zacks, 2006). Spatial perspective taking is indispensable for navigation, spatial orientation, and smooth movement (Kozhevnikov et al., 2006; Watanabe, 2016). Thus, it plays an important role in our daily lives.

Previous studies indicated that males' mental rotation and spatial perception were superior to those of females (e.g., Lauer & Lourenco, 2019). In line with this, studies have demonstrated that, compared with males, females have an obvious disadvantage in various abilities related to spatial perspective-taking, such as parking skills (Wolf et al., 2010), direction estimation (Holding & Holding, 1989), and map studying (Galati et al., 2018). More directly, in a recent study, Zancada-Menendez et al. (Zancada-Menendez et al., 2016) found that female adults also performed worse than males adults on a standard measure of spatial perspective taking. These studies indicated that, just as their performance on other spatial tasks, females' spatial perspective taking is not as good as males' in general. From the perspective of evolutionary psychology, male's superiority of spatial ability is the evolutionary result of sexual selection (Jones et al., 2003). This theory argues that spatial cognition is linked to hunting skills and related to wayfinding ability or range size of activity, leading males to perform better on related tasks (Levine et al., 2016). In contrast, another viewpoint from the social

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psychology perspective states that socio-cultural factors like stereotype threat have been demonstrated to be the important reasons for gender differences in spatial ability (Neuburger et al., 2015; Ruthsatz et al., 2012).

In gender studies, the influence of stereotype threat on females' various cognitive abilities, including spatial cognition, has been extensively documented (Doyle & Voyer, 2016; Flore & Wicherts, 2015). As an ability that is closely related to spatial cognition, it is natural to expect females' spatial perspective taking might be impaired by stereotype threat. Stereotype threat can undermine the performance of stigmatized individuals in tasks that are related to the stereotype. There are numerous negative stereotypes of females in traditional belief systems. For example, females are often considered to be emotional, with good language abilities, but poor in math and spatial awareness. These stereotypes have extensive effects on females' performance in various fields, such as STEM (science, technology, engineering, and mathematics) (Shapiro & Williams, 2012), athletic performance (Hively & El-Alayli, 2014), leadership (Hoyt & Blascovich, 2007), and so on. Notably, performance decline caused by stereotype threat has also been widely described in research about spatial abilities for both adolescent and adult females (Moè & Pazzaglia, 2006; Sharps et al., 1993). For example, females in a stereotype threat condition obtained lower average scores on tests of spatial reasoning (McGlone & Aronson, 2006). Similarly, Neuburger et al. (2015) examined the mental rotation performance of 272 boys and girls and found boys outperformed girls when girls were in a stereotype threat condition.

Although stereotype threat impairs females' performance on certain spatial tasks, to the best of our knowledge, no study has examined the effect of stereotype threat on females' spatial perspective taking directly. In this study, female university students were recruited as participants to address this issue. We hypothesized that gender stereotype threat impairs females' spatial perspective taking. That is to say, females who were primed by a negative stereotype threat would perform worse on a spatial perspective-taking task than those who were not primed with a stereotype threat.

Further, we also aimed to explore the underlying mechanism of the effect of gender stereotype threat on females' spatial perspective-taking. Discussion about the underlying mechanisms of stereotype threat has emphasized the importance of executive function (Schmader et al., 2008), which refers to the advanced cognitive processes required by individuals to complete target tasks (Kessels & Hendriks, 2015). Executive function can coordinate various cognitive processes when individuals complete complex cognitive tasks, so that an individual's cognitive system remains flexible and optimized for them to complete the targeted task (Li et al., 2004).

A common structure of executive function divides it into three components: inhibition, updating, and shifting (Miyake et al., 2000). Inhibition refers to the ability to consciously control spontaneous responses (Miyake et al., 2000). It consists of internally generated control reactions to avoid "spontaneous error" and is a core component of behaviors involving self-control and self-regulation (Mittal et al., 2015). Updating, which is related to working memory, refers to an individual's use of attentional control to maintain relevant information in the face of interference and to replace old information with new (Friedman et al., 2006). The essence of updating is dynamically manipulating relevant information in the working memory rather than just passively storing the information (Miyake et al., 2000). Shifting is the ability to effectively switch between multiple tasks (Miyake et al., 2000). As such, it is an important part of cognitive flexibility and is the basis for creativity and helps individuals adapt to changing conditions (Park et al., 2018).

Previous studies have consistently concluded that stereotype threat impacts executive functions, especially for inhibition and updating. For example, Black students and female students showed impaired inhibitory control on the Stroop task when race and gender stereotype threats were activated (Inzlicht et al., 2006). Rydell et al. (2014) found females under stereotype threat showed reduced inhibition and updating. However, few studies have found impaired shifting under stereotype threat.

The effect of stereotype threat on spatial perspective-taking is more likely to be mediated by inhibition. According to previous literature, inhibition has a closer relationship than updating or shifting with perspective taking. For example, to complete an emotion understanding task, children had to inhibit a spontaneous reaction of taking their own perspectives in order to take others' perspectives (Hughes et al., 1998). Studies about spatial perspective taking yielded similar results. For instance, Qureshi and Monk (2018) obtained consistent results showing that inhibition was involved in controlling responses resulting from one's own perspectives in spatial perspective taking. Brunsdon et al. (2017) tested spatial perspective-taking ability of young adults, middle-aged adults, and the elderly and found that poorer inhibitory control may be the reason for the lower perspective-taking ability of older adults. These studies indicate that young adults' perspective taking is better predicted by inhibition than by updating or shifting. Therefore, combining the impact of stereotype threat on inhibition and the important role of inhibition in spatial perspective taking, we predicted that reduced inhibition may account for the effect of stereotype threat on females' spatial perspective-taking ability.

The Current Study

Through two experiments, this study investigated the effects of stereotype threat on females' spatial perspective-taking ability and the possible cognitive mechanism. Experiment 1 explored whether stereotype threat would decrease females' spatial perspective-taking ability. In this experiment, female participants were randomly assigned to a stereotype threat group or a control group and then required to complete a spatial perspective-taking task. Similarly, in Experiment 2 female university students were also recruited as participants and randomly assigned to a stereotype threat group and a control group. Before the spatial perspective-taking task, they were asked to complete three executive function tasks (including an inhibition task, an updating task, and a shifting task). We examined the impact of stereotype threat on the inhibition, shifting, or updating components of executive function, as well as on females' spatial perspective-taking ability. Next, we tested whether the effect of stereotype threat on spatial perspective taking could be mediated by certain components of executive function.

Experiment 1

In Experiment 1, we brought participants into the lab and randomly assigned them to a control condition or a stereotype threat condition. We compared the performance on the perspective-taking task between the control condition and the stereotype threat condition, expecting that females' perspective-taking performance would be lower in the stereotype threat condition than in the control condition.

Previous studies found that individuals' group identification affects the activation of stereotype threat (Kang & Chasteen, 2009). When individuals strongly identify with social groups, they are more vulnerable to stereotype threat (Marx et al., 2005). Therefore, in this experiment, we measured gender identification as a covariate variable.

Method

Participants

A total of 76 undergraduates *(mean age* = 18.36 years ±1.17 *SD*) were randomly recruited as participants in return for ¥10. All participants were females (38 in the control condition and 38 in the stereotype threat condition). There was no significant difference in age between the stereotype threat group (M = 18.32, SD = 1.25) and the control group (M = 18.39, SD = 1.10), t (74) = 0.29, p = .772, d = 0.06.

Procedure

First, participants were asked to report demographic information and the gender identification scale when they arrived at the lab. After this, the participants were randomly assigned into a stereotype threat condition or a control condition, and then they were instructed to read different brief reports depending on their conditions (stereotype threat manipulation). After a stereotype or a neutral prime, participants completed the spatial perspective-taking task. Finally, they completed the manipulation check scale and were then debriefed. All participants were tested individually.

Materials

Gender Identification We used the dimension of "Importance to Identity" in the Collective Self-Esteem Scale (Luhtanen & Crocker, 1992) to measure gender identification. The scale had good reliability and adequate structural validity. There were four items in the scale, and participants were asked to respond on a 7-point Likert scale from 1 (*strongly disagree*) to 7 (*strongly agree*). The items were "Overall, my gender has very little to do with how I feel about myself (reverse scored)", "My gender group is an important reflection of who I am", "My gender is unimportant to my sense of what kind of a person I am (reverse scored)" and "In general, my gender group is an important part of my self-image". Scores across the four items were averaged to form an index of gender identification (α = .71). Higher scores denoted higher gender identification.

Stereotype Threat Manipulation Participants in the stereotype threat condition were given a brief report stating that perspective taking is a spatial ability in which males have an advantage over females and then portrayed the aim of the current study as that of measuring people's spatial ability. The following negatively framed article was used to trigger gender stereotype threat (159 Chinese characters):

> Spatial ability is a category of reasoning skills that refers to the capacity to think about objects in three dimensions and to draw conclusions about those objects from limited information. As an important cognitive ability, spatial ability is valuable in many real-world situations, like navigation, parking. Studies have shown that spatial ability differs significantly between genders. Males tend to perform better than females in related tasks. After reading the above material, to further explore spatial ability in females, a spatial test, which can capture accurately individuals' spatial ability, will be conducted following this report.

Participants in the control condition were given a neutral article, which introduced basic information about poplar trees (160 Chinese characters) and portrayed the aim of the current study as that of measuring people's reading ability. The following excerpt illustrates this:

Poplar is the most widely distributed and adaptable tree species in the world, mainly distributed in the temperate zone and cold temperate zone of the northern hemisphere. China has abundant poplar resources, and China's natural poplar forest area is about 3 million hectares from Populus suaveolens Fisch and Populus ussuriensis Kom in the northernmost part of China, to the Populus yunnanensis Dode in the south. There are also drought-tolerant, salt-tolerant Populus euphratica in the west, as well as Populus alba L and Populus canescens. Because poplar has the characteristics of early rapid growth and asexual reproduction, people can use planting poplar to form plantations to solve some ecological problems. After reading the above material, to further explore reading ability, a test, which can measure individuals' reading-related ability, will be conducted following this report.

Perspective-Taking Test The experiments used a pencil-and-paper spatial perspective-taking test, which was created by Hegarty and Waller (2004) (see Fig. 1 for an example), to measure the spatial perspective-taking ability. In the test, participants were shown an array of objects. A statement instructed participants to imagine standing in the place of one object on the map and facing another object. They needed to indicate the direction to a third object (e.g., "Imagine you are standing at the cat and facing the tree. Point to the car."). Below the array of objects was a circle with an arrow that pointed toward

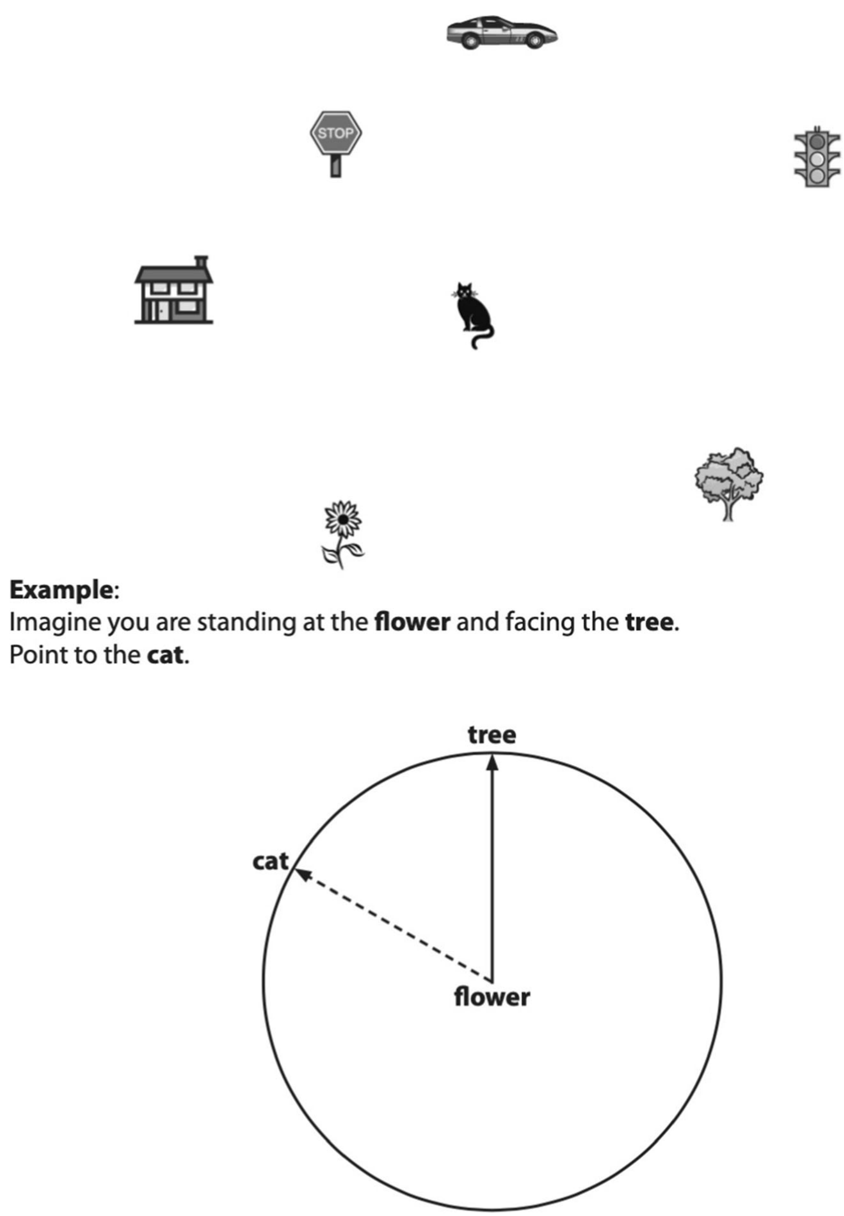

Fig. 1 Example trial from the original spatial perspective-taking test (Hegarty & Waller, 2004)

the object that participants imagined facing. Participants were asked to draw a second arrow to indicate the direction to the third object. There were 12 items in total in this test, which needed to be completed in 5 min. Participants' responses were scored by calculating the absolute angular deviation from the correct answer for each trial (which could range from 0° to 180°) and averaging these errors across trials. Greater angular deviations denoted lower spatial perspective-taking ability.

Manipulation Check For the manipulation check, participants were asked to indicate how much they agreed with the following three statements, which were adapted from items used in Marx's (2012) study: "I worry that my ability to perform well on spatial perspective-taking tests is affected by my gender", "I am worried that if I perform poorly on this test, the experimenter will attribute my poor performance to my gender" and "I worry that, because I know the negative stereotype about females, my anxiety about confirming that stereotype will negatively influence how I perform on the tests". Responses were recorded on a Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). We averaged the responses to form a measure of the threat appraisal ($\alpha = .72$). Higher scores denoted higher stereotype threat.

Results

Manipulation Check

An independent t test showed that the score of the stereotype threat group ($M = 2.89$, $SD = 1.29$) was significantly higher than that of the control group ($M = 2.21$, $SD = .98$), $t\ (74) = -2.61$, $p = .011$, $d = .60$. Thus, the manipulation of the stereotype threat was effective.

Gender Identification

An independent t test showed that there was no significant difference in gender identification between the stereotype threat group ($M = 6.03$, $SD = .74$) and the control group ($M = 5.93$, $SD = .93$), $t\ (74) = -0.55$, $p = .59$, $d = 0.12$. Thus, activating the stereotype threat was not affected by participants' gender identification.

Spatial Perspective-Taking Performance

We conducted a single factor (stereotype threat condition vs. control condition) between-subjects analysis of covariance (ANCOVA) on the angular deviation in the spatial perspective-taking task by including gender identification as a covariate. The degree of deviation from the correct direction (angular error) differed significantly between the stereotype threat condition and the control condition, $F\ (1,\ 74) = 10.06$, $p = .002$, $\eta^2 = .12$. The angular error was higher in the stereotype threat condition ($M = 37.07°$, $SD = 22.31$) than in the control condition ($M = 23.77°$, $SD = 15.89$). A post-hoc power analysis using G*Power 3.1.9 (Erdfelder et al., 2009) indicated that we were sufficiently powered (observed statistical power = .89) to detect a medium-sized effect. This result suggested that females' performance on the perspective-taking task was undermined when stereotype threat was activated.

Discussion

Findings obtained from Experiment 1 were fully consistent with our prediction that females would perform worse on the spatial perspective-taking task in the stereotype threat condition. This revealed that stereotype threat had a negative effect on female perspective-taking ability. However, in order to eliminate the potential contingency of Experiment 1's results, we designed Experiment 2 to replicate the results. Also, Experiment 1 did not explore the mechanism of the effect of stereotype threat on perspective-taking ability, especially the role of the three components of executive function. Based on these limitations, we conducted Experiment 2.

Experiment 2

In Experiment 2, we not only attempted to replicate the results of Experiment 1 but also further explored the role of three components of executive function between stereotype threat and perspective-taking performance. In Experiment 2, participants were randomly assigned to a stereotype threat condition and a control condition. After that, they were asked to complete three executive function tasks on the computer. Finally, the spatial perspective-taking test was completed.

Method

Participants

Eighty-four female undergraduate students participated in this study for ¥10. Seven participants were excluded from the analyses due to equipment malfunction ($n = 1$), not completing the perspective-taking test as required ($n = 2$), or extreme outliers on executive function measures ($n = 4$). The remaining 77 (*mean age* = 18.53 years ±1.17 SD) participants were included in the analyses. There were 40 participants in the stereotype threat condition. There was no significant difference in age between the conditions, $t\ (75) = -\ 0.53$, $p = .600$.

Procedure

First, the participants were asked to fill out demographic information and the gender identification scale when they arrived at the lab. Then, they were given the same manipulation of stereotype threat used in Experiment 1. Following this manipulation, they completed the three tasks (Stroop task, local–global task, and keep track task) that measured each of the executive function components (inhibition, shifting, and updating, respectively). The order of the three tasks was randomized for each participant. After that, the participants were asked to complete the spatial perspective-taking test and manipulation check scales.

Materials

The materials for gender identification ($\alpha = .71$), spatial perspective-taking test, and manipulation check ($\alpha = .66$) were identical to those used in Experiment 1. Unlike Experiment 1, three tasks that measure the three components of executive function were included following the manipulation of stereotype threat. Participants were asked to complete the three executive function tasks on the computer. E-prime 2.0 software was used to present the stimulus and record the responses in these three executive function tasks.

Inhibition The Stroop (1935) task was used to measure inhibition. In this task, participants were asked to indicate the color of the text (blue, red, yellow, or green) of a color word (e.g., the word RED), which was presented at the center of the computer screen, by pressing one of four response keys. According to previous studies (e.g. Rydell et al., 2014; Yow & Li, 2015), at the beginning of each trial, participants were presented with a fixation cross in the center of the computer screen for 500 ms, followed by a random presentation of a color word, which remained on the screen for 3000 ms. Participants completed a total of 96 trials, including 48 incongruent trials and 48 congruent trials. In the 48 incongruent trials, the color word was presented in a different colored text (e.g., BLUE was presented in red text). In the 48 congruent trials, the color word and the color of the text were the same (e.g., BLUE printed in blue text). The inhibition score was calculated by subtracting the average reaction time of the incongruent trials from that of the congruent trials, with higher scores denoting greater inhibition.

Shifting The local–global task (Miyake et al., 2000) was modified to measure shifting. In this test, we used the "Navon figure" (Navon, 1977). The lines of the "global" figure (e.g., a triangle) were composed of much smaller "local" figures (e.g., squares). Depending on the color of the figure (red or green), participants were instructed to press one of four response keys (i.e., 1 for a circle, 2 for a triangle, 3 for a square, and 4 for an "X"). If the figure was green, participants needed to report the identity of the global figure; if, instead, the figure was red, then they were to report the local figure. The local–global task's number of trials and timing of stimuli were based on previous studies (Brown et al., 2013; Wang et al., 2017). Participants completed two blocks consisting of 96 trials in total (i.e., 48 trials in each block). In each block, starting from the second trial, when the figure was presented in the same color as the previous trial, it was a no-shift trial; when the figure's color was different from the previous trial, it was a shift trial. In total, there were 47 no-shift trials and 47 shift trials. In each trial, the stimulus remained on the screen for 3000 ms. The shifting score was calculated by subtracting the average reaction time of the shift trials from the average reaction time of the no-shift trials. Higher scores indicated greater shifting ability.

Updating Yntema's keeping track task (Yntema, 1963) was modified to measure the updating ability according to some recent studies (Ito et al., 2015; Rydell et al., 2014). The experimental materials were changed to Chinese words (every word included two characters) with a high frequency of use. In this task, participants completed 12 trials. Each trial consisted of 15 items that came from six categories (fruits, cities, sports, occupations, animals, and stationery). These items were presented serially on the center of the screen (each was presented for 1000 ms) and three, four, or five target categories remained at the bottom of the screen. The goal of the task was to recall the last word presented in each of the target categories and then type these words at the end of the trial. For example, if the target categories were fruits, cities, and sports, participants were told, "The target categories are fruits, cities, and sports. Please type the last fruit, the last city, and the last sport that you saw listed." In total, participants were given 48 items to recall. Higher number of correctly recalled items denoted a greater updating ability.

Results

Manipulation Check

An independent t test showed that the score of stereotype threat group ($M = 3.57$, $SD = 1.41$) was significantly higher than that of the control group ($M = 2.70$, $SD = 1.14$), $t\,(75) = -2.93$, $p = .004$, $d = .69$. Therefore, the manipulation of stereotype threat was effective in Experiment 2.

Gender Identification

There was no significant difference in gender identification between the stereotype threat group ($M = 6.18$, $SD = 1.11$) and the control group ($M = 6.32$, $SD = .97$), $t\,(75) = 0.16$, $p = .871$, $d = .13$.

Executive Function Tasks

The effect of stereotype threat on each of the executive function tasks was examined by using a single factor (stereotype threat condition vs. control condition) between-subject analysis of covariance (ANCOVA) with inhibition, updating, shifting, and spatial perspective-taking performance as dependent variables and gender identification as a covariance variable.

Inhibition There was a significant effect of stereotype threat on the inhibition task, F (1, 75) = 11.40, p = .001, η^2 = .13. Females under threat showed lower inhibition (M = −159.41 ms, SD = 83.13) than females in the control condition (M = −105.19 ms, SD = 52.17), indicating that stereotype threat reduced the inhibition function. The post-hoc power analysis confirmed that power was adequate (observed statistical power = .92).

Updating The results for the updating task also showed a significant effect of stereotype threat, F (1, 75) = 5.54, p = .021, η^2 = .07. Females showed poorer updating performance in the stereotype threat condition (M = 29.58, SD = 3.08) than in the control condition (M = 31.51, SD = 4.05), indicating that stereotype threat also negatively impacted the updating function. The post-hoc power analysis indicated that power was 0.66.

Shifting However, there was no significant effect of stereotype threat on shifting, F (1, 75) = 0.30, p = .613, η^2 = .003 ($M_{Control}$ = −162.15 ms, $SD_{Control}$ = 157.41; $M_{Stereotype\ threat}$ = −177.94 ms, $SD_{\mathrm{Stereotype\ threat}}$ = 118.44). Thus, the shifting function was not affected by stereotype threat.

Spatial Perspective-Taking Performance

With respect to their spatial perspective taking, females in the stereotype threat condition showed higher angular deviation (M = 25.83°, SD = 10.23) than females in the control condition (M = 17.75°, SD = 8.15), F (1, 75) = 14.28, p = .000, η^2 = .16. The post-hoc power analysis showed that power was adequate (observed statistical power = .97). This suggests that the females' spatial perspective-taking performance was affected by stereotype threat. The results replicated the results obtained from Experiment 1.

Correlations between Variables

The intercorrelations between the variables in Experiment 2 are provided in Table 1. There was a significant positive correlation between the inhibition and spatial perspective-taking measures. However, the correlation between the shifting and the perspective-taking measures as well as the correlation between the updating and the perspective-taking measures were not significant. We also found that inhibition was correlated with updating but was not correlated with shifting. Updating was not correlated with shifting.

Table 1 Pearson product-moment correlational coefficients among variables in Experiment 2 (N = 77)

	1	2	3	4	5
1 Group	–				
2 Spatial perspective taking	.403***	–			
3 Inhibition	−.365***	−.662***	–		
4 Updating	−.264*	−.190	.243*	–	
5 Shifting	−.058	.096	.081	.038	–

* $p \le .05$; ** $p \le .01$; *** $p \le .001$; group was dummy coded such that 1 = stereotype threat condition and 0 = control condition

Mediation Analysis

Finally, a multiple mediation analysis was carried out to test whether the inhibition function accounted for the impact of stereotype threat on females' spatial perspective taking. Preacher and Hayes' (2008) bootstrapping procedure for models with multiple mediators for examining mediation with small samples was employed. In this analysis, the experimental conditions (coded 1 for the stereotype threat condition and 0 for the control condition) were regarded as independent variables, inhibition, updating, and shifting as mediating variables, spatial perspective-taking ability as the dependent variable, and gender identification as a covariate variable. This model simultaneously examined the indirect effects whereby stereotype threat predicted the three components of executive function, which in turn predicted perspective taking (see Fig. 2). The analysis used 5000 resamples with replacement to obtain a 95% confidence bias-corrected confidence interval for the indirect effect of stereotype threat condition on perspective-taking ability as transmitted via the three components of executive function. The model took into account the direct effect of stereotype threat on perspective taking when the three components of executive function scores were considered. The mediation model was estimated to derive the direct, indirect, and total effects of stereotype threat on females' spatial perspective taking.

The results showed that although stereotype threat was related to both the inhibition task and the updating task, only the mediation effect of the inhibition task on the relationship between stereotype threat and perspective taking was significant (indirect effect = .44, $BootSE$ = 0.15, 95% BootCI [+0.1798, + 0.7587]). The mediating effects of updating (indirect effect = −.0034, $BootSE$ = 0.04, 95% BootCI [− 0.0790, +0.0736]) and shifting (indirect effect = −.02, $BootSE$ = 0.04,

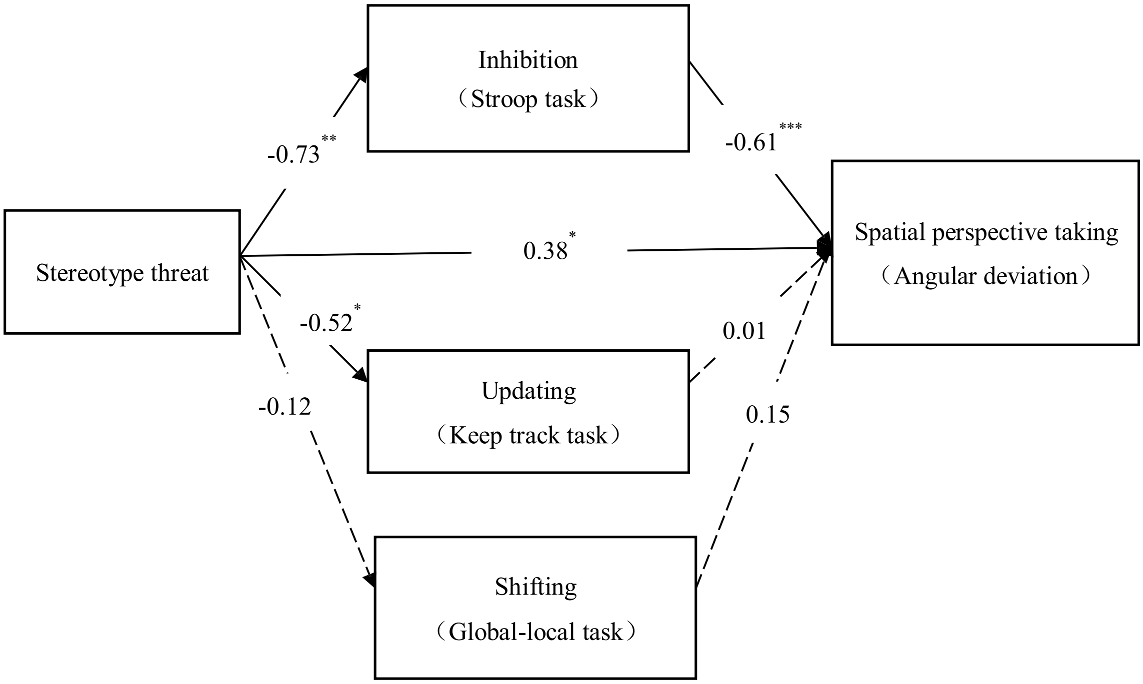

Fig. 2 A path diagram showing the interaction of stereotype threat on females' perspective-taking ability as mediated through the inhibition, updating, and shifting components of executive function in Experiment 2. Note. All scores are standardized beta weights. * $p \le .05$; ** $p \le .01$; *** $p \le .001$

95% BootCI [−0.1448, +0.0511]) were not significant. Specifically, we found that the direct effect of stereotype threat on the angular deviation of spatial perspective-taking test was statistically significant (direct effect = .38, $SE = .18$, $t = 2.06$, 95% CI [+0.0128, +0.7460]). Stereotype threat also had significant negative effects on both inhibition ($b = -.73$, $SE = 0.22$, $t = -3.38$, 95% CI [−1.5114, −0.2979]) and updating ($b = -.52$, $SE = 0.22$, $t = -2.35$, 95% CI [−0.9608, −0.0800]), but no significant effect on shifting ($b = -.12$, $SE = 0.23$ $t = -0.51$, 95% CI [−0.5760, +0.3417]. Furthermore, inhibition negatively predicted the angular deviation of the spatial perspective-taking test ($b = -.61$, $SE = 0.09$, $t = -6.59$, 95% CI [−0.7912, −0.4237]). However, the effects of updating and shifting on the spatial perspective-taking test ($b = .01$, $SE = 0.09$, $t = 0.07$, 95% CI [−0.1720, +0.1852], and $b = .15$, $SE = 0.08$, $t = 1.81$, 95% CI [−0.0156, +0.3232], respectively) were not significant. Thus, stereotype threat not only directly affected females' spatial perspective-taking ability but also damaged it through the inhibition function.

Discussion

The results of Experiment 2 verified the negative impact of stereotype threat on females' spatial perspective-taking, replicating the results obtained from Experiment 1. The results also showed that stereotype threat negatively impacted the inhibition and updating components of executive function. The results of the multiple mediation analysis indicated that inhibition mediated the relationship between stereotype threat and females' spatial perspective taking. That is, the negative impact of stereotype threat on spatial perspective-taking ability was partially caused by reduced inhibition. In addition, stereotype threat decreased the updating ability, but neither updating nor shifting mediated the effect of stereotype threat. These findings further detailed the cognitive mechanism of the effect of stereotype threat on spatial perspective-taking performance.

General Discussion

The current study explored the effect of stereotype threat on females' spatial perspective taking and identified a possible cognitive mechanism. In Experiment 1, the results indicated that stereotype threat had a negative effect on females' spatial perspective-taking ability. The results of Experiment 2 showed that stereotype threat decreased the inhibition component of executive function, which in turn reduced females' spatial perspective taking ability. Importantly, our research found that two of the three executive functions, inhibition and updating, were affected by stereotype threat, but only inhibition played an intermediary role.

First, our results showed that a stereotype threat impaired females' spatial perspective taking. These results were consistent with previous research about the relationship between stereotype threat and other spatial abilities (e.g. Delgado &

Prieto, 2008; Heil et al., 2012; McGlone & Aronson, 2006; Sanchis-Segura et al., 2018). Previous studies paid more attention to mental rotation, possibly because mental rotation was considered to have a large gender difference (Linn & Petersen, 1985). Although mental rotation and spatial perspective taking may share some common processes such as encoding and maintaining mental representations, researchers believe that mental rotation and perspective taking depend on different types of spatial transformation (i.e., object-based spatial transformation and egocentric spatial transformation, respectively) (Hegarty & Waller, 2004) and different neural structures (Zacks et al., 1999a; Zacks et al., 1999b; Zacks et al., 2000). Therefore, our research on spatial perspective taking is meaningful and enriches the research structure in the field of stereotype threat and spatial ability.

Second, our study found that stereotype threat impairs executive functions. Specifically, the inhibition and updating components of executive function were lower in the stereotype threat condition than in the control condition. In earlier studies, executive function has been treated as a single variable without consideration of its components or has been one-sidedly understood as inhibitory control. Executive function has both a unified and a diverse structure. Recent research has focused on the relationship between stereotype threat and different components of executive function. Consistent with our findings, previous studies have found that stereotype threat could cause a decline in the inhibition function (Inzlicht et al., 2006) and the updating function (Rydell et al., 2014). Schmader et al. (2008) proposed that stereotype threat led to poor performance via depleted executive resources. Specifically, coping with threat depletes limited regulatory resources, which could lead to subsequent deficits in inhibitory control. In addition, negative emotions are aroused in the context of stereotype threat, which might impair the updating function because greater emotional reactivity has been linked to declined updating function (Berger et al., 2018; Pe et al., 2015). Thus, the probable reason is that a negative stereotype threat leads to a reduction in self-regulation (Schmader et al., 2008) or an increase in negative emotion (Johns et al., 2008), resulting in a lowering of inhibition and updating. With respect to shifting, to our knowledge no research has shown that stereotype threat reduces the shifting function. Individuals might engage in a large amount of shifting to try to get out of the threat (Rydell et al., 2014). Thus, shifting should not be impaired by stereotype threat.

It is worth noting that some researchers have been unable to replicate the effect of stereotype threat on inhibitory control. Pennington et al. (2019) found that stereotype threat did not significantly impair females' inhibitory control and mathematical performance across two experiments. Their sample sizes were small (i.e., 20 participants in each condition), which could increase the risk of type 2 errors. The experiment 2 of Hutter et al. (2018) also didn't replicate the effect of stereotype threat on inhibitory control. However, in this experiment the manipulation check was not significantly different between the stereotype threat group and the control group, which means "the setting could have been insufficiently threatening for stereotype threat effects to occur" (Flore et al., 2018).

Finally, although inhibition and updating were negatively affected by stereotype threat, only the decline in the inhibition function was related to the decline in females' spatial perspective-taking ability. Rydell et al. (2014) suggested that the impact of stereotype threat on different outcomes may be mediated by different executive functions. Our experimental results support this perspective in that the impact of stereotype threat on spatial perspective taking was not mediated by the entire set of executive functions. The test of spatial perspective taking neither requires participants to store and maintain information, nor requires participants to switch between different tasks. Thus, updating and shifting should not significantly affect the performance of spatial perspective taking. Instead, as mentioned above, inhibitory control is an important part of the process of completing a perspective taking task (Wardlow, 2013). Standing in one's own perspective might be an initial impulse that people need to control to make a more accurate judgment from another's perspective. Therefore, reduced inhibition in response to a stereotype threat can reasonably account for decreased spatial perspective taking.

Implication and Limitation

This study has important theoretical and practical implications. Previous studies have examined gender differences in spatial perspective taking (Tarampi et al., 2016; Zancada-Menendez et al. 2016). However, no research directly explored the effect of stereotype threat on spatial perspective taking. Our research focused on the negative impact of stereotype threat activation on females' spatial perspective taking and the mediating role of inhibition. These results can enrich both stereotype threat theory and spatial perspective-taking theory. We demonstrated that, when the females encountered a stereotype threat, their spatial perspective-taking ability decreased. Our research provides clues that could be used in future intervention studies to eliminate the negative effect of stereotype threat and improve the ability to take another person's perspective. In a social context, it is necessary to minimize the activation of stereotype threat, especially when females need to use spatial perspective-taking ability to overcome the limitations of egocentric perspective, psychologically transform their own position to the other's position, and obtain other's visual representations. Some intervention programs, such as providing "gender fair" information (Boucher et al., 2012), and promoting self-affirmation (Martens et al., 2006), should be given to avoid the activation of female stereotype threat to reduce the occurrence of spatial transformation deviation. Future laboratory-based studies could also use intervention measures to strengthen the inhibition function and, in turn, to improve the perspective-taking ability.

There are some limitations in this study. First, the study used a paper-and-pencil test developed by Hegarty and Waller (2004) for the measurement of spatial perspective taking. Although the test has been used in many studies, it is displayed as two-dimensional pictures and is different from a real-life scene. Fisher et al. (2018) found that the form of the stimuli of mental rotation task could affect females' performance and eliminate the sex difference in mental rotation task. Thus, three-dimensional models with VR technology can potentially be used to improve the validity of the test in future research. Second, this study focused on spatial perspective taking, which can be seen as one aspect of perspective taking that also includes social perspective taking. However, spatial and social perspective taking are not completely independent from each other. Future researchers could examine the stereotype threat effect on social perspective taking or a combination of social and spatial perspective taking. Next, as mentioned above, previous studies suggested that stereotype threat could affect individuals' self-regulation or emotions, which might deplete executive resources, leading to poor performance (Johns et al., 2008; Schmader et al., 2008). Thus, future research can further detail the relationship between stereotype threat and different components of executive functions, and consider baseline levels of individuals' executive functions. Further, previous studies found certain factors, such as brain activation (Hugdahl et al., 2006) and strategy choice (Hegarty, 2018), may contribute to the gender difference in spatial perspective taking. Future studies can investigate whether these factors also play a mediating role in the relationship between stereotype threat and spatial perspective taking, in addition to the partial mediation of the inhibition function we found here. Finally, the correlations between measures of executive functions in our second experiment were low and similar to those obtained by Miyake et al. (2000, Appendix A), which supports the diversity of executive functions. Future research can use multiple paradigms to measure the convergent and discriminant validity of different components, and further verify the findings of the current study.

Conclusion

Overall, our results show that stereotype threat has a negative impact on females' performance in spatial perspective-taking ability. And the present study provides further evidence for the role of executive function. Specifically, stereotype threat reduces females' inhibition and updating functions, rather than their shifting function. The inhibition function plays a mediating role in the relationship between stereotype threat and females' spatial perspective taking.

Acknowledgements This research was supported by the National Nature Science Foundation of China (31200778) and the Swedish Research Council (2018-06664).

Code Availability Not applicable

Authors' Contributions All authors contributed to the study conception and design. Yao Lin, as the first author was responsible for data analysis and drafting of the article. Baoshan Zhang, as the corresponding author designed the study and revised the paper. Dou Jin and Heyating Zhang, collaborated with data collection. All authors commented on previous versions of the manuscript. Junhua Dang, collaborated with revising the paper. All authors read and approved the final manuscript.

Funding This research was supported by the National Nature Science Foundation of China (31200778) and the Swedish Research Council (2018-06664).

Data Availability The materials and data are available on the OSF (https://osf.io/kuymd/?view_only=764a2a0472a14107b7b6a6b48edc3321).

Declarations

Ethics Approval All procedures performed in studies involving human participants were in accordance with ethical standards of the university research committee and with the 1964 Helsinki declaration.

Consent to Participate Informed consent was obtained from all participants included in this research.

Consent for Publication Not applicable.

Conflicts of Interest/Competing Interests On behalf of all authors, the corresponding author states that there is no conflict of interest.

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