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Sex differences and the effect of instruction on reorientation abilities by humans

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Abstract

This study examined whether differences in the amount of information provided to men and women, in the form of verbal instruction, influenced their encoding during a reorientation task. When a navigator needs to orient, featural (e.g., colour or texture) and geometry (e.g., metric information) are used to determine which direction to begin traveling. The current study used a spatial reorientation task to examine how men and women use featural and geometric cues and whether the content of the task's instructions influenced how these cues were used. Participants were trained to find a target location in a rectangular room with distinctive objects situated at each corner. Once the participants were accurately locating the target, various tests manipulating the spatial information were conducted. We found both men and women encoded the featural cues, and even though the features provided reliable information, participants generally showed an encoding of geometry. However, when participants were not provided with any information about the spatial aspects of the task in the instructions, they failed to encode geometry. We also found that women used distant featural cues as landmarks when the featural cue closest to the target was removed, whereas men did not. Yet, when the two types of cues were placed in conflict, both sexes weighed featural cues more heavily than geometric cues. The content of the task instructions also influenced how cues were relied upon in this conflict situation. Our results have important implications for our understanding of how spatial cues are used for reorientation.

Keywords Human · Reorientation · Feature · Geometry · Sex differences · Task instructions

Successful navigation within an environment requires efficient processing of spatial information. This study examined peoples' ability to achieve the first step of navigation—orientation. Orientation refers to the determination of the relative position or direction of oneself within an environment. If the navigator cannot successfully orient, they will become lost. Cheng (1986) was the first to study the use of environmental geometry for reorientation (establishing a sense of direction after disorientation) by showing that rats could use the shape of a rectangular enclosure to locate a hidden food reward during a search task. Cheng trained rats, using a reference memory task, to find a food reward hidden in a fully enclosed rectangular arena. A distinctive panel was positioned at each corner of the enclosure—each panel had a unique combination of colour, pattern, texture, and olfactory cues (featural information). During this task, the shape produced by the walls of the enclosed search space provided geometric information (e.g., distance and directional cues). Interestingly, Cheng found that although the rats could learn to limit their searching to the single rewarded corner, they showed systematic errors, as they often searched at the corner diagonally opposite to where the reward was located. Cheng reported the rats had not only learned about the distinctive featural cues but had incidentally encoded the geometric information from the shape of the enclosure. Following Cheng's initial investigation, many other studies have been conducted, providing supporting evidence that most species studied to date show an ability to encode geometry (for a review, see Cheng, Huttenlocher, & Newcombe, 2013; Cheng & Newcombe, 2005). Focusing on research with humans, the ability to encode geometry has been shown in children around the age of 2 (e.g., Gouteux, Vauclair, & Thinus-Blanc, 1999; Hermer & Spelke, 1994; Lourenco & Cabrera, 2015), with featural and geometric information being integrated by the age of 3,

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whereas by adulthood geometric and featural cues are readily integrated to form a representation of one's spatial environment (e.g., Cheng et al., 2013; Hermer & Spelke, 1994; Kelly & Bischof, 2005; Kelly & Spetch, 2004; Ratliff & Newcombe, 2008b; Sturz & Diemer, 2010; Sturz, Forloines, & Bodily, 2012; Sutton, Joanisse, & Newcombe, 2010).

Studies of cue use for orientation and reorientation (herein referred to as "reorientation," for simplicity) have examined the use of featural and geometric cues in a variety of different environments. For example, Kelly and Spetch (2004) examined how adults use featural and geometric cues when the spatial environment was presented as two-dimensional (2-D) schematic images. During training, participants were shown overhead views of a schematic rectangular environment on a computer monitor. The environment was rectangular, with distinctively coloured and shaped objects at each corner. The participants' task was to locate the corner consistently associated with reinforcement. Once the participants were accurately locating the correct corner, they were presented with nonreinforced testing trials that systematically manipulated various aspects of the environment. For instance, during one test, all the distinctive features were removed. The researchers found that participants were able to concentrate their searches on the two geometrically correct corners when the features were not available, supporting the conclusion that participants had incidentally encoded the geometric information during training. This result is important, as it shows participants learned about the environmental geometry even when this information was not necessary to solve the initial task. Indeed, the task would be solved more accurately using features rather than geometry. Similar results have been reported during studies requiring adult participants to reorient in three-dimensional virtual environments (e.g., Driscoll, Hamilton, Yeo, Brooks, & Sutherland, 2005; Jansen, Schmelter, & Heil, 2009; Kelly & Bischof, 2005; Sjölinder, Höök, Nilsson, & Andersson, 2005). Together, these studies show that adults incidentally encode geometric information when reorienting in many different types of environments. Thus, the first aim of our study was to confirm that adults show incidental encoding of geometric information in a navigable environment.

Previous research has shown men and women use different aspects of the environment when orienting and navigating. For example, Saucier et al. (2002) showed when participants were asked to navigate to four unknown destinations in a real-world setting, men tended to perform more accurately when using geometric cues (e.g., distances and cardinal directions), whereas women tended to perform more accurately when using featural cues (e.g., landmarks). Another study examined how adult participants navigated in a desktop-displayed virtual reality environment when given either directional (i.e., geometric) or positional (i.e., featural) cues (Chai & Jacobs, 2009). In the directional-cue environment, the test arena was located on a small hill with a terrain slant of approximately 30° and had landmarks forming an environmental boundary which gave the participant geometric information. In the positional-cue environments, the test arena was situated on a flat terrain containing landmarks of different configurations within the arena which gave the participant featural information. The researchers reported that men arrived closer to the target location compared with women in both environments. However, the difference between men and women's accuracy during navigation was greater in the directional-cue environment, with men performing most accurately, supporting men's use of geometric information. Similar studies, using a virtual Morris Water Maze, further report that men perform significantly faster than women when finding a hidden platform (Astur, Tropp, Sava, Constable, & Markus, 2004; Driscoll et al., 2005). Considering the overall results from these studies, and others of a similar nature, generally, we may conclude that men and women use different strategies during navigation. Thus, it is important to understand whether the differential use of spatial cues by men and women differs from the initiation of navigation, when individuals are orienting within an environment.

Men and women may attend to different properties of a spatial environment when they are required to orient. As discussed above, this difference may be due to men and women relying on different spatial cues—encoding of geometry or features—but sex differences may also exist in how men and women use a particular spatial cue—for instance, how features are used (Hughes, Sulikowski, & Burke, 2014). A navigator may encode features distant to a goal location such that any one of these distal cues may be used as a landmark to determine the position of the goal. Contrastingly, a navigator may only encode the feature directly at the goal location, as a beacon, such that moving toward the feature leads directly to the goal (e.g., Waller & Lippa, 2007). One study examining cue use in rats found females tended to rely more heavily on distal landmarks rather than beacons at the goal location, whereas the males did not (Tropp & Markus, 2001). Research has also shown men and women encode geometry differently when orienting in an environment, and these differences start at a young age. Children were shown a toy being hidden in a distinctive container at one corner of a rectangular room, thus the container functioned as a beacon. When the beacon was removed, and only geometric information remained, boys searched for the toy in the geometrically appropriate corners more than girls, and only boys searched at these corners significantly above chance (Lourenco, Addy, Huttenlocher, & Fabian, 2011). This suggests that even at a young age, boys rely more heavily on geometric cues than girls. This difference in encoding and cue use continues into adulthood, such that men tend to use geometric information more readily, whereas women tend to use featural information more readily (Kelly & Bischof, 2008). In one study, adult men and women navigated through a virtual water maze that contained both geometric and featural information. Manipulation of cues in the environment revealed that women relied predominantly on featural information, whereas men relied more readily use both featural and geometric information (Sandstrom, Kaufman, & Huettel, 1998). During the condition in which only geometric information was available, men were significantly faster than women at finding the hidden platform. Thus, the second aim of our study was to examine how flexibly men and women use cues during reorientation in a navigable environment.

Although previous research has shown adults integrate featural and geometric cues and use these two cues independently, few studies have examined whether one type of cue is preferentially relied upon over another when the two cues provide conflicting information. For instance, using a nonimmersive virtual reality environment, Kelly and Bischof (2005) trained participants to find a goal within a rectangular environment, with each corner containing a distinctive feature. To examine cue weighing, the participants were given a cue-conflict test, in which each feature was relocated one position clockwise. This manipulation placed the feature associated with reinforcement in a geometrically incorrect corner, and, likewise, the two geometrically correct corners now contained unreinforced features. The results of the study showed that both men and women weighed featural cues more heavily than geometric cues—they searched more often at the corner that contained the reinforced feature (also see Ratliff & Newcombe, 2008b). Thus, the third aim of our study was to examine whether men and women show preferential use, or weighing, when features and geometry provide conflicting information when reorienting in a navigable environment, allowing for a comparison to our previous studies using virtual environments.

During studies of reorientation, little focus has been directed to understanding how the content of task instructions may influence how features and geometry are encoded. However, Ratliff and Newcombe (2008a) examined whether language influences how features and geometry are used during a spatial reorientation task. Using a dual-task paradigm, participants were asked to perform a verbal shadowing task while performing a reorientation task. The researchers found that participants who were required to verbally shadow were less likely to use features to reorient, but this effect was found only when participants lacked explicit information regarding the nature of the task, and only in a small room. Focusing on the navigational processes after reorientation, Tom and Denis (2003) examined the effects of instructional content by giving participants either landmark-based (e.g., “Turn right toward the phone booths”) or street-based instructions (“Turn right into Jean Bouveri Street”) before the participants performed a way-finding task in a navigable environment. When the participants were navigating, the researchers noted three types of actions: directional errors, “checkings,” and stops. Directional errors included all deviations from the intended route. Checkings referred to a verbally expressed intention to check a piece of information (for instance, a street name). Finally, stops were defined as pauses lasting more than 2 seconds. Although directional errors did not differ between instruction groups, the participants given street-based instructions performed more checkings compared with those given landmark-based instructions. Furthermore, the participants given the landmark-based instructions made fewer stops compared with the participants given the street-based instructions.

Instructions provided during studies examining children’s use of featural and geometric information during reorientation tasks often explicitly mention the features in the environment. For example, during a study by Hermer and Spelke (1994), the experimenter would point out to the child the particular feature associated with the hidden toy, allowing the child to physically play with the feature before asking the child to find the hidden toy in the corner of a rectangular room. However, the instructions in these studies did not include similarly explicit referencing to the distinctive geometric information provided by the shape of the environment (as this was the primary variable of study). Furthermore, many studies of reorientation have not explicitly examined whether the content of the task instructions influence how features and geometry are encoded. Therefore, in the present study, we provided groups of participants different sets of task instructions to examine whether the content of these instructions influenced how features and geometry were encoded or relied upon. Thus, the fourth and final aim of our current study was to examine whether instructions influence the use of cues by adults when reorienting in a navigable environment.

In summary, the current project examined (1) whether men and women incidentally encode geometry in a navigable environment, (2) whether men and women differ in whether distant features are used as landmarks, (3) whether men and women weigh featural and geometric cues differently when these cues provide conflicting information, and (4) whether the content of the task instructions influence cue use.

Method

Participants

One hundred and forty-one participants (71 women, 70 men), ages 17–41 years (M = 20 years), were recruited from the University of Saskatchewan’s Psychology 110 participant pool. All participants received an extra two credits towards their Psychology 110 class grade. All procedures were approved by the Senate Committee on Ethics in Human Research and the University of Saskatchewan. Informed consent was obtained from all participants prior to completing the tasks.

Apparatus

The experimental room was rectangular (3.65 m × 5.49 m). Each wall was covered with an opaque, white curtain, spanning from ceiling to floor. A layer of shredded paper covered the floor to obscure possible visual cues. The ceiling had uniform tiles and lights, such that there were no distinguishable directional cues. During training trials, four objects were present; one in each corner of the room (herein, objects will be referred to as *features*). These four features were constructed of Styrofoam® and consisted of a green *X*, a red six-sided polygon, a blue arrow, and an orange triangle, each fitting within a space approximately 50 cm^3; for a schematic, see Fig. 1). Centered in front of each feature was a small tin container (7 cm diameter × 3.5 cm deep), covered with a brown plastic lid. The experimental room was equipped with a video camera mounted in the center of the ceiling. The camera was connected to a Sony® Digital Video Cassette Recorder (Model GV-D1000 NTSC) located outside the experimental arena, permitting the recording and monitoring of all experimental sessions. All cabling was routed through the ceiling so as not to be visible in the experimental room.

General procedure

Participants arrived to a small waiting room, where they were seated, asked to read and sign an informed consent form, and verbally instructed on how to complete the experiment (see Instruction Groups section, below).

Prior to arrival, each participant was assigned a corner of the environment which would be reinforced (A, B, C, or D; herein referred to as the *positive corner;* see Fig. 1a). The corner assignment was counterbalanced across participants. During training, a coin (as reinforcement) was placed inside the container positioned in front of the feature at the positive corner, whereas the other three containers were always empty. During training, the position of the featural cues within the room was consistent; therefore, the positive corner always contained the same featural cue across trials (herein referred to as the *positive feature*) for a participant (i.e., a reference memory task).

Training

Prior to the start of an experimental trial, participants wore a blindfold, so they were unable to see the entrance into the experimental room, and wore earplugs, to block any auditory cues. To begin each training trial, the researcher led the participant to an arbitrary location within the experimental room where the participant was guided to turn in slow circles clockwise and counterclockwise. This procedure was used to ensure the participant was disoriented and unable to use any inertial cues. Next, the participant was lead to one of four possible starting positions at the center of a wall in the experimental room (starting position was counterbalanced across

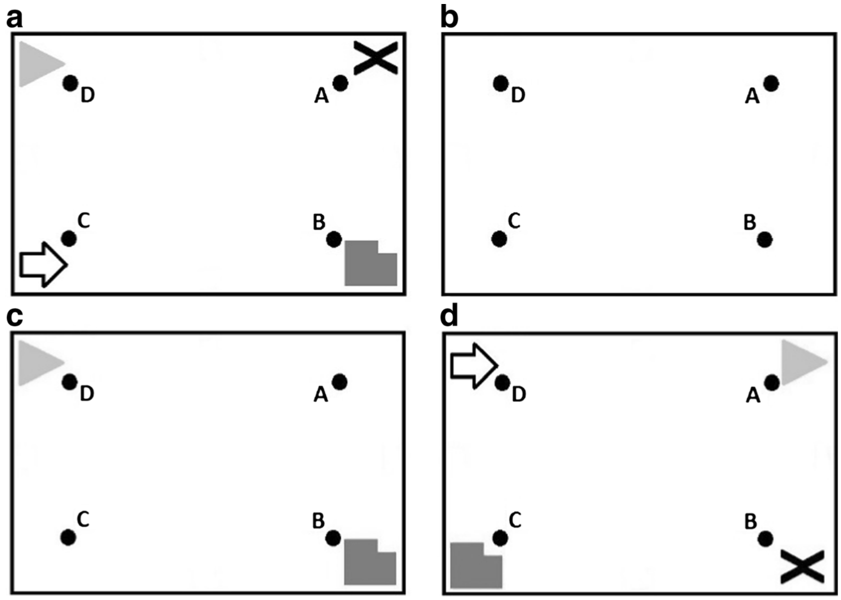

Fig. 1 Schematic examples of the room used in training and testing: (**a**) training, (**b**) geometry-only condition, (**c**) distal condition, and (**d**) cue-conflict condition. The training example shows a feature in each of the corners, a green *X* (represented as black in this figure), a red polygon (represented as dark gray in this figure), a blue arrow (represented as white with a black outline in this figure), and an orange triangle (represented as light gray in this figure). For the purpose of illustration, the examples for the test conditions are drawn as if the *X* (Corner A) was assigned as the positive feature, although this was counterbalanced across participants. The four black filled circles represent the identical response containers in each corner. The letters associated with these containers are for descriptive reference only. The schematics are not drawn to scale, as they are for illustrative purposes only

trials). Once at the starting location, the participant was instructed to remove the blindfold and earplugs, and requested to search the containers for the coin by picking up one container at a time and shaking it. This allowed the participant to determine whether the coin was inside, indicating a correct choice. Participants were asked to continue making choices until the correct container was found. Once participants found the reinforced container, they were asked to reinsert the earplugs and replace the blindfold, after which the participant was again disoriented before being led out of the experimental room and into the waiting room. The participant remained in the waiting room while the researcher prepared the experimental room for the next trial (e.g., randomly scattered the paper shredding and replaced the containers). Each participant completed a total of eight training trials. To reach the training criterion, the participant had to locate the positive corner on their first choice during the last two training trials (seven and eight). Once the training criterion was achieved, the participant advanced to testing. If a participant did not meet the training criterion, they were thanked for participating, and the experiment was ended (data from these participants were not included in any analyses).

Testing

Upon completion of training, participants were presented with three consecutive test conditions, with order of condition counterbalanced across participants. The general procedures for the test trials were the same as the training trials. However, during the testing trials, one spatial property of the environment was manipulated (see conditions below), and all trials were nonreinforced (i.e., no coin was present in the positive container).

Geometry-only condition During the geometry-only condition, the four distinctive features were removed from the corners, leaving only the geometry provided by the rectangular shape of the room. Responses during this condition showed whether the participants had encoded the geometric information during training when the features were present. It should be noted that encoding the geometry during training was not necessary as the features provided sufficient information about the location of the reinforced container to allow the participant to be 100% correct. If participants had encoded geometry, we would expect their choices to be directed only to the two geometrically correct corners; the two geometrically incorrect corners should be avoided.

Distal condition During the distal condition, the feature in the positive corner and the feature in the diagonally opposite corner were removed. Responses during this condition showed whether the participants had encoded the featural cues in the corners distal to the positive corner. Participants could encode only the feature in the positive corner (i.e., a beaconing strategy), or the location of the positive corner could be encoded relative to some or all the features in the other three corners (i.e., landmark strategy). A beaconing strategy alone would not allow the participants to differentiate between the two now "featureless" corners, whereas if the participant had learned about any of the features in the two geometrically incorrect corners, these could be used to determine the location of the positive corner. Therefore, we expected that if participants had encoded either of the distal featural cues, they should direct their searches to the positive corner.

Cue-conflict condition During the cue-conflict condition, each feature was moved one position clockwise, placing the featural and geometric information in conflict. The cue-conflict condition allowed for the examination of cue weighing. If participants weighed the featural information more heavily than the geometric information, we would expect more choices to be made to the corner with the positive feature from training (although now situated in a geometrically incorrect corner). However, if the participants were weighing the geometric information more heavily than the featural information, more choices should be made to the geometrically correct corners (although each now with incorrect features). A third possibility is that the participants might weigh features and geometry equally, in which case choices should be distributed equally among the three corners, with few or no choices made to the single corner containing incorrect featural and geometric information.

Each participant completed the entire experiment during one 50-minute session. Upon completion of the study, each participant was provided with a debriefing form explaining the study, provided with a verbal debriefing, and given an opportunity to raise any questions or concerns.

Instruction groups

All participants experienced the same training and testing procedures as described above, but prior to starting the experiment, they were given one of three sets of instructions (depending on group assignment): no information (NI), feature and geometry information (FGI), or feature information (FI; copies of the instructions are provided in the Appendix). The NI instructions were designed to give participants as few spatial cues as possible; no information about the geometry of the room or the features present within the room was included in these instructions. The FGI instructions were designed to point out the rectangular shape of the room (i.e., global geometric information) and the four distinctively coloured features (i.e., featural information) located at each corner. Finally, the FI instructions were designed to draw the participants' attention only to the feature in the positive corner (i.e., "Look, I am placing the container with the coin right here beside this big ‘red’ object”). The FI instructions were included in the study to approximate those used in several studies of geometric and featural cue use by children (e.g., Gouteux et al. 1999; Lourenco & Huttenlocher, 2006).

Data analysis

All choices made by the participants were recorded, although only the first choices made during the testing trials were used for analyses. A choice was defined as when the participant touched one of the tins with his or her hand. For the purposes of analyses, choices made by the participants were defined by the testing condition (i.e., features present [or not present], the relation of the features present [or not present] in the other three corners, as well as the relation of the positive feature originally assigned to the participant). Participant choices during training and testing were coded twice, each by a different researcher naïve to the predictions of the study (interrater reliability was 94.21%). In situations where the two researchers differed, the researchers discussed and came to a unanimous agreement.

The nonparametric Scheirer–Ray–Hare test, an equivalent to a parametric factorial analysis of variance, was used for initial analyses of the between-subjects variables sex and instruction group. Significant effects were further examined by Wilcoxon signed-rank tests to compare proportion of choices made to a corner to chance level responding, as well as to compare the proportion of choices made to two particular corners. A Kruskal–Wallis test was used to examine choices among each instruction group in the cue-conflict condition. All tests were evaluated using the significance level of $p < .05$.

Out of 141 participants, seven failed to successfully complete the training trials and did not proceed to the test trials (two from the NI instruction group and five from the FGI instruction group). First choices were analyzed for 46 participants (22 females, 24 males) in the NI instruction group, 48 participants (24 females, 24 males) in the FI instruction group, and 40 participants (20 females, 20 males) in the FGI instruction group.

Results

Geometry-only condition

For analysis of the geometry-only condition, the corner that contained the positive feature during training was labeled as the *correct* corner. The corner diagonally opposite to the correct corner was labeled as the *rotational* corner (Note: the correct corner and the rotational corner are both geometrically correct and indistinguishable when distinctive features are not available). For this condition, all features were removed; therefore, participants were required to rely only on geometric information from the shape of the environment to reorient. The proportion of choices made to the two geometrically correct corners ($M = .66$) was not affected by sex, Scheirer–Ray–Hare: $H(1) = .25$, $p = .617$, but instruction group was marginally significant, Scheirer–Ray–Hare: $H(2) = 5.56$, $p = .062$. There was no significant interaction found between instruction group and sex, $H(2) = 2.97$, $p = .227$. Participants in the NI group ($M = .54$) did not choose the geometrically correct corners more than expected by chance (Wilcoxon: $Z = 587.5$, $p = .555$), and were unable to distinguish between the correct corner ($M = .22$) and the rotational corner (Wilcoxon: $M = .33$; Z = 1.00, $p = .317$). However, the participants in the FI ($M = .77$) and FGI ($M = .68$) groups did choose the geometrically correct corners more than expected by chance (Wilcoxon: $Z = 906.5$, $p < .001$, and $Z = 553.5$, $p = .027$, respectively; see Fig. 2). In the FI and FGI groups, the participants were unable to distinguish between the correct corner ($M = .42$; $M = .33$, respectively) and the rotational corner (Wilcoxon: $M = .36$, Z = .493, $p = .622$; $M = .35$, Z = .192, $p = .847$, respectively), supporting the assumption that participants were using geometric information when making their decisions and not an uncontrolled cue (and confirming the disorientation procedure was successful). Overall, these results show that when participants were provided with instructions indicating some component of the spatial information available, they encoded geometry during training and were able to use that geometric information to identify the possible target location when feature cues were removed. However, not providing participants with some indication as to the spatial relationship of the target location impeded the encoding of geometry.

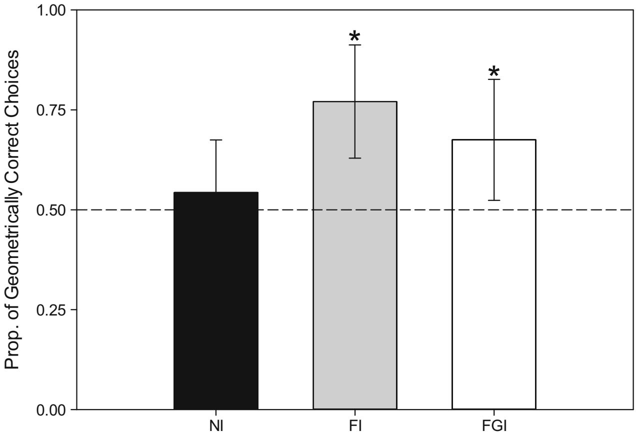

Fig. 2 Mean proportion of choices to the two geometrically correct corners (correct and rotational corners summed) by men and women, for each instruction group (no information, featural information, and featural and geometric information, respectively), during the geometry-only condition. The dashed line indicates chance level (50%). Error bars represent standard errors of the means. * indicates responses significantly greater than chance

Distal condition

For analysis of the distal condition, the corner that would have contained the positive feature during training was labeled as the *correct* corner. The purpose of the distal condition was to determine if participants used the remaining features in the two geometrically incorrect corners as landmarks to identify the location of the correct corner. Proportion of choices to the correct corner (M = .46, M = .52, M = .37) did not differ among the instruction groups, Scheirer–Ray–Hare: $H(2)$ = 1.87, p = .393. However, sex did have a significant effect on proportion of choices to the correct corner, Scheirer–Ray–Hare: $H(1) = 4.38$, $p = .036$, suggesting that men and women used the cues differently. Women were able to choose the correct corner significantly more than the rotational corner (Wilcoxon: Z = 2.77, p = .006), whereas men, regardless of instruction group, were not (Wilcoxon: $Z = .00$, $p = 1.000$; and Z = 0.23, 0.71, and 0.83, $ps > .1$, for instructional groups NI, FI, and FGI, respectively; see Fig. 3). Furthermore, men, regardless of instruction group, were not able to discriminate between the correct and rotational corner. Overall, these results support that women had encoded some of the distal features and were able to use this landmark information to isolate the correct corner. Men, however, only encoded the feature in the correct corner as a beacon; when this feature was not available, they fell back to a geometric strategy or avoided the corners with incorrect features.

Cue-conflict condition

For analysis of the cue-conflict condition, the corner that would have contained the positive feature during training was labeled as the *geometric* corner. The corner one position clockwise, which now contained the positive feature, was labeled as the *feature* corner. The corner diagonally opposite to the geometric corner was labeled as the *rotational* corner. Finally, the corner located diagonally opposite the feature corner was labeled as the *incorrect* corner. For the cue-conflict condition, it was hypothesized that participants would weigh featural cues over geometric cues, as suggested by previous research (Kelly & Bischof, 2005; Ratliff & Newcombe, 2008b; Sturz & Diemer, 2010). Therefore, for our initial analyses we examined proportion of choices to the feature corner as our dependent variable. The proportion of choices to the feature corner (M = .81) did not differ as a function of sex, Scheirer–Ray–Hare: $H(1) = .30$, $p = .585$, whereas instruction group had a significant effect, Scheirer–Ray–Hare: $H(1) = 4.50$, $p = .013$. These results suggest that the content of the instructions provided to the groups resulted in the participants differentially weighing features and geometry (see Fig. 4). There was no significant interaction found between instruction group and sex, Scheirer–Ray–Hare: $H(2) = .08$, $p = .616$. Further analysis of the differences in choices among each instruction group showed the only significant difference was the proportion of choices to the feature corner by participants in the FI instruction group (M = .67) and the FGI instruction group (M = .93; Kruskal–Wallis: H = 15.91, p = .014). Although instruction group did influence the degree to which features were weighed over geometry, participants made a greater proportion of their choices to the feature corner than the other three corners for all three instruction groups, NI ($M = .85$), FI ($M = .67$), and FGI ($M = .93$; Wilcoxon: $Z = 4.72$, $p < .001$; $Z = 2.95$, $p < .05$; $Z = 5.60$, $p < .001$, respectively). Furthermore, although the three instruction groups differed in the proportion of choices made to the two geometrically correct corners (i.e., geometric and rotational corners summed), NI (M = .15), FI (M = .27), and FGI (M = .05); Kruskal–Wallis: H = 7.77, p = .021, these were

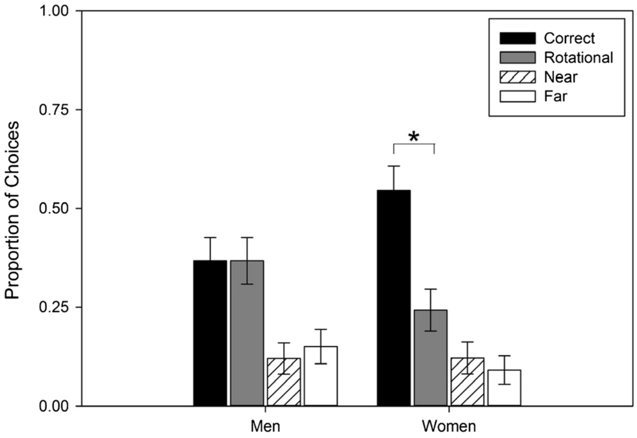

Fig. 3 Mean proportion of choices to all corners, separated by sex, for the distal condition. Error bars represent standard errors of the means. * indicates a significant difference between proportion of choices to the two indicated corners

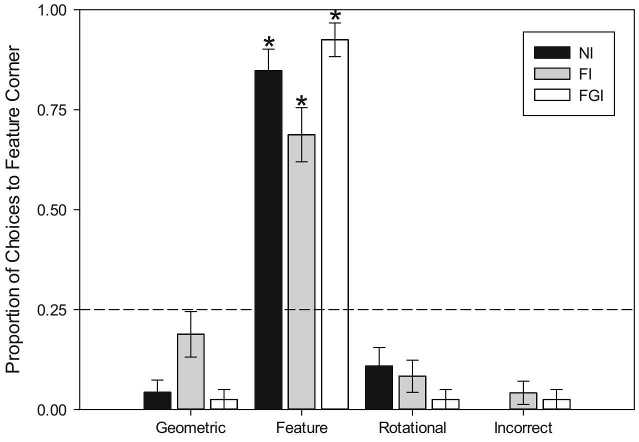

Fig. 4 Mean proportion of choices to the corners, separated by instruction group, during the cue-conflict condition. The corner diagonally opposite to the *geometric* corner was labeled as the *rotational* corner. The corner containing the positive feature from training was labeled as the *feature* corner. The corner diagonally opposite to the feature corner was labeled as the *incorrect* corner. Error bars represent standard errors of the means. * indicates significantly greater proportion of choices compared with chance (0.25 indicated by dashed line)

significantly less than expected by chance (Wilcoxon: $Z = 2.11$, $p = .035$). However, to further understand the distribution of choices for the FI instruction group, as this group showed the lowest proportion of choices to the feature corner, we analysed the proportion of choices to the geometric corner and the rotational corner across groups. The proportion of choices to the geometric corner was greater for the FI instruction group compared with the other groups (Kruskal–Wallis: $H = 8.82$, $p = .012$), but there was no difference in proportion of choices to the rotational corner among the groups (Kruskal–Wallis: $H = 2.24$, $p = .327$). Interestingly, this was the corner where the positive feature was located during training; thus, for the participants in the FI instruction group, who were trained with an emphasis on features, this location may have accumulated greater associative strength (see the Discussion section for more detail). Despite these differences, all groups weighed featural information over geometry.

Discussion

During this experiment, we examined how adult men and women use geometric and featural information when reorienting in a navigable environment, and whether the content of the instructional information had an effect on reorientation. First, we examined if adults incidentally encoded geometric information when trained with distinctive featural information present. Second, we examined whether men and women used distant featural cues differently. Third, we examined the weighing of features and geometry when these cues were put in conflict. Finally, for all testing conditions, we examined whether the type of instructions given to the participants influenced how they used these cues. Supporting previous research, we found both men and women, in the FI instruction group, distinguished the geometrically correct corners from the geometrically incorrect corners in a navigable environment. This suggests that both sexes in this group had incidentally encoded geometry when trained to find a target location in a navigable environment with distinctive features present (e.g., Hermer & Spelke, 1996; Kelly & Bischof, 2005; Sutton et al., 2010; Sturz et al., 2012).

Although men and women both showed an encoding of features and geometry, the way these cues were used during reorientation differed. When the positive feature was no longer available, women used distal features to guide their choices to the correct corner (e.g., a landmark strategy), whereas men did not, suggesting men may have only learned the target location with reference to the positive feature (e.g., a beacon strategy). Men may have also used a geometric strategy when the positive feature was unavailable, or they simply avoided the unrewarded features. Although our current results are unable to distinguish between these two alternatives, it is clear they were not able to use the distal features as landmarks.

The results from the distal condition suggest men and women were attending to the spatial information differently during training. This sex difference is supported by previous research, which also showed that men and women used different cues, either landmark or Euclidean (e.g., use of distances, geometric information, cardinal directions) after learning a route on a map. Galea and Kimura (1993) asked participants to learn and successively retrace the learned route on a map. During that study, women remembered more landmarks, both on and off the learned route, compared with men, whereas men outperformed women in their knowledge of the Euclidean properties of the map. Thus, women weighed featural information more heavily, whereas men weighed geometric information more heavily in their learning of the spatial route. Correspondingly, Dabbs and colleagues asked participants to study a route on a map and then to write down directions as if telling a friend how to get from one place to another (Dabbs, Chang, Strong, & Milun, 1998). The researchers found that men used more Euclidean information and fewer landmarks when giving directions compared with women. Dabbs et al. also showed that women remembered more landmarks both on and off a route compared with men. Overall, the results of our study, and of previous research, suggest even though both men and women encode geometry and use feature and geometric cues, the way in which they use these cues may differ.

When featural and geometric cues were placed in conflict during the cue-conflict condition, our results showed both men and women relied more heavily on featural cues than geometry, which supports results from previous computer-based, nonnavigable research (Kelly & Spetch, 2004; Sturz & Diemer, 2010) as well as studies using navigable environments (Sturz, Brown, & Kelly, 2009; Lourenco et al., 2011).

The results from our study provide insight into how subtle differences in the type of instruction provided to participants may influence their use of features and geometry. Instructions were found to influence the ability to encode geometry, as the participants who were not given any explicit spatial information did not encode geometry during the geometry-only condition, whereas the other two groups did. It is interesting to note that even the group provided with instructions, that pointed out the featural cues (but not the geometry), showed an incidental encoding of geometry. This result aligns with previous research showing that features may facilitate the encoding of geometry (Cheng & Newcombe, 2006; Kelly, 2010; Lourenco & Cabrera, 2015). Another point is that the FGI instruction group was provided with instructions stating that the goal was located in a "rectangular room"—global geometric information. Therefore, although this group clearly encoded the geometric information during training, we cannot conclude whether this was truly incidental encoding or rather due to the explicit instructions.

Instructional content, however, did not support differences in whether the distal features were encoded (distal condition). Although instructions may have had more of an influence if attention was drawn to all the distal features, as opposed to just one feature (as in our study). Smith et al. (2008) performed a study aimed to examine young children's ability to use distal cues during reorientation. These researchers found that children as young as 3 years old could accurately identify the target location using the distal feature cues present in the environment.

Instructional information significantly influenced how features and geometry were weighed when these cues were placed in conflict (cue-conflict condition). Participants in the NI and FGI instruction groups weighed features more heavily compared with participants in the FI instruction group. However, this difference only influenced the *degree* to which features were weighed, as all groups relied more heavily on features—following the correct feature into a geometrically incorrect location, regardless of instruction type. One must recall that participants who were not provided with any spatial information in their instructions (NI instruction group) did not encode geometry. Therefore, for these participants, there likely was not a conflict situation between features and geometry. However, it is less clear why providing participants with featural information would cause them to rely *less* on features than those provided with no instructions or with featural and geometric information. For the FI instruction group, the instructions refer explicitly to "this object in this corner," whereas in for the FGI instruction group, the only explicit reference to the geometry of the room is a passing mention that the room was rectangular. Perhaps some of the participants may not have realized the importance of that statement as a guiding cue. In addition, the FGI instruction group has the curtains on the wall described as being there to "ensure you cannot differentiate one wall from another." By telling the participants that they cannot differentiate one wall from another, it is possible that the FGI instructions group may have been inadvertently biased to not attend to wall length information (i.e., geometry), although the participants in this group did choose the geometric corner more than the other two groups. Finally, the geometry corner was the original position of the positive feature during training. Therefore, the geometry corner, and its close proximity to the now relocated postive feature, may have had greater associative strength for the FI group given the feature-biased instructions. However, overall, none of the groups chose the geometrically correct corners more than expected by chance, supporting a heavier weighing of features over geometry by all instruction groups.

Overall, this study provides a necessary step in determining whether instructions influenced reorientation in a navigable environment. These results further our current knowledge as we showed sex differences in how geometric and featural information is used. This study also supports that the content of the task instructions affects cue use, and as such, future studies examining cue use should carefully consider the influence of instructional content. The results from this study allow us to better understand how adults encode and use the spatial properties of an environment during reorientation and provide insight of adults' ability to navigate. These findings have important implications for furthering our understanding not only of reorientation strategies but also of sex differences in the way this information is used and the influence of instructions during the first step of navigation—orientation.

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Appendix

No information (NI) instructions

Thank you for participating in this study.

You will be asked to wear a blindfold and earplugs during this experiment. Do you have any concerns about this request?

We will begin the study from this little room. I will ask you to put on your blindfold so that you cannot see anything, and I will ask that you wear earplugs. I will then carefully lead you into another room. Once we are in this room, I will show you where I am going to place a container that has a coin in it (*show container and shake it*). I will then ask you to slowly turn in circles. I will stay close by, in case you get dizzy. I will then ask you to remove your blindfold. At this point, you will see four tin containers, like this one here. Your goal is to try to find the container with the hidden coin as quickly, and with as few choices, as possible. So, you will need to pick up the container that you think contains the coin and shake it. Once you find the coin, I will ask you to put your blindfold back on, and I will lead you back to the small waiting room. We will do this several times.

It is important to know that at first I will let you choose as many containers as you need to find the coin, but after a few times I will limit the number of choices you can make. It is also important to know that the coin will not be present on every trial, but I still would like you to try and pick the container you think most likely contains the coin.

Do you have any questions about these procedures?

So, just to recap, when you are in the room, you need to pick the container that you think has a coin in it—try to make your choices as quickly but as accurately as possible

Feature information (FI) instructions

Thank you for participating in this study.

You will be asked to wear a blindfold and earplugs during this experiment. Do you have any concerns about this request?

We will begin the study from this little room. I will ask you to put on your blindfold so that you cannot see anything, and I will ask that you wear earplugs. I will then carefully lead you into another room. Once we are in this room, I will show you where I am going to place a container that has a coin in it (*show container and shake it*). I will then ask you to slowly turn in circles. I will stay close by, in case you get dizzy. I will then ask you to remove your blindfold. At this point, you will see four tin containers, like this one here. Your goal is to try to find the container with the hidden coin as quickly, and with as few choices, as possible. So, you will need to pick up the container that you think contains the coin and shake it. Once you find the coin, I will ask you to put your blindfold back on, and I will lead you back to the small waiting room. We will do this several times.

It is important to know that at first I will let you choose as many containers as you need to find the coin, but after a few times, I will limit the number of choices you can make. It is also important to know that the coin will not be present on every trial, but I still would like you to try and pick the container you think most likely contains the coin.

Do you have any questions about these procedures?

So, just to recap, when you are in the room, you need to pick the container that you think has a coin in it—try to make your choices as quickly but as accurately as possible.

Once the experiment starts:

When you show the person where you are placing the container with the coin, say the following (replace 'red' with the correct colour):

"Look, I am placing the container with the coin right here beside this big 'red' object in this corner."

Feature and geometry information (FGI) instructions

This is an orientation and navigation task. You will be given earplugs (please ensure that they are firmly placed into your ears) and will then be blindfolded.

I will lead you into the testing room: It is a rectangular room with white drapes from ceiling to floor, and the floor is covered in paper shredding. Both of these conditions are to ensure that you cannot differentiate one wall from another, or are able to orient yourself by markings on the floor.

In the testing room, I will walk you to a spot where you are to remain while I make some adjustments to the door. Afterward, I will assist in slowly spinning you. Please remember to pick up your feet, as there is shredding on the floor.

Once you are disoriented, I will walk you to a spot, and you can then take your blindfold off. Inside the room, you will see that there is a coloured feature in each corner, and in front of each feature there will be a small tin with a lid.

It is your task to search these tins for a hidden goal (in this case, a penny). You may just give the tins a quick shake to determine if the penny is inside. Once you've found the goal, you will be blindfolded again, disoriented, and led out of the room, back into the waiting room. I will then go back inside the testing room for a few moments, and the procedure will start over again.

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