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Human Spatial Representation: Looking at Sex Differences For Processing Geometric Information

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ABSTRACT

Spatial ability is a part of memory that is responsible for recording information about one's environment and its spatial orientation. For example, a person's spatial memory is required in order to navigate around a familiar city, just as a rat's spatial memory is needed to learn the location of food at the end of a maze. This current study focuses on whether sex differences appear on such spatially loaded tasks. Research has shown that males do in fact perform better on spatial loaded tasks than females. Participants were to remember the location of a red dot on a rotating rectangle on two tasks. The first task included featural information, (a white stripe on one side) and the other task had no featural information. On the first task, no differences were found. On the second task males performed differently. Results of the study indicate that males relied purely on geometric properties of the rectangle while females relied more on featural information when locating a target in the environment.

Spatial ability is perhaps the most vital aspect of human mental capabilities. Without the ability to comprehend and interpret spatial information humans would not be able to locate objects or ourselves in the surrounding environment (Learmonth, Newcombe, & Huttenlocher, 2001). Most, if not all animals have the ability to navigate through space. Some animals depend on this ability to recover stored food, while others depend on it to get them home at the end of the day. Whatever the task may be, the organism's survival depends on the use and accuracy of some physiological mechanism that allows it to navigate through space. One fundamental way of exploring, learning and finding a way around surroundings is path integration. Path integration is the process that allows an animal to deduce their position in relation to a point of departure from their own movement (Templeton, 1966). For example, the *Cataglyphus*, the long legged desert ant will search for food many meters on a twisting outgoing path away from their nest, when they find food they are able to travel directly straight back to their nest. Many people get mistaken and believe the ants are scent marking (Brodbeck, 2007 lecture). If the ants were scent marking then they would trace their scent marks back towards their nest (Brodbeck 2007 lecture).

A second type of method animal's use for navigating is landmarking. Landmarks offer visual cues that are useful in calibrating/mapping where you are in space. Landmarks are simply objects in fixed locations. When an animal is too far away to see the goal, it may use fixed objects that are closer in order to navigate back to their departure point. In order to do this the animal must choose objects (landmarks) along the way and encode them into memory in a sequence that will get them to the goal (Wiltschko & Wiltschko, 1998). In the first investigation of using landmarks, Cheng

(1986) found that rats would use distinctive features (e.g., brightness of walls) at the expense of geometry when searching for food. Eventually, the rats relied on the shape of the apparatus to locate the target, searching equally at the location of the target and the geometrically equivalent location at the opposite side of the rectangular apparatus (i.e., in the corner located at 180° rotation from the target to the center). Given that rats were able to use nongeometric information for solving the task, these finding suggest that spatial orientation depends on an encapsulated, task-specific mechanism (Cheng, 1986; Cheng & Gallistel, 1984), a geometric module. Cheng was able to conclude that rotational errors implied that animals were using the shape of the apparatus to reorient, and ignored obvious featural information. Cheng predicted that the animal's behaviour indicated a geometric module for reorientation which allows the animal to encode the shape of the environment (Cheng, 1986; Cheng & Spetch, 1998; Gallistel, 1990; Vallortigara et al., 1990). Geometric properties can be described by their position in space relative to other surfaces, lines or points. This also includes measures such as direction, distance and angles. The geometric module would use only metric properties, the distinction between a long and short wall; and sense which is the distinction between left and right. A featural (or non-geometric) property is a type of property which includes measures such as colour, texture, or size (Cheng & Spetch, 1998; Gallistel, 1990). Therefore a geometric module is a specially designed module that engages animals on the geometric properties of a target relevant to the positions in the environment.

Developmental research on spatial reorientation mechanisms has shown that geometric features are spontaneously taken into account by young children and predominate over local nongeometric cues, even when the latter would allow distinction between geometrically similar places (Hermer & Spelke, 1996). When disoriented in a familiar rectangular room, perfectly homogeneous and without distinctive featural information, young children aged 16-24 months and 3-4 years old rely on the large-scale geometry of the room to reorient themselves (Hermer & Spelke, 1994). The children were shown a toy brought from home by their parents. The children observed as the toy was hidden in a corner of a rectangular (Hermer & Spelke, 1994; 1996; Learmonth et al., 2001; 2002), square (Wang et al., 1999), or cylindrical (Gouteux & Hermer, 2001) environment. To disorient the children the parents would pick up the child, covered his or hers eyes and turn them for at least four full revolutions. Older children were able to close their eyes and turn the required revolution without parental assistance. Results showed that children performed successfully using featural information regarding the hiding location to find the hidden object (Hermer & Spelke, 1996). Other experiments involved testing in featureless environments where all walls of the environment were white (Gouteux & Hermer, 2001; Hermer, 1997; Hermer & Spelke 1994, 1996; Learmonth et al., 2001; Learmonth et al., 2002; Wang, Hermer & Spelke, 1999). Others used environments with large-scale features (e.g., one blue wall, 3 white walls), while others used different geometric cues (e.g., distinctive geometric arrangement of boxes or distinctively shaped wall, Gouteux & Hermer, 2001; Learmonth et al., 2001; Wang et al., 1999).

A wealth of information has been provided by Hermer, Spelke and colleagues regarding children's reorientation abilities. They have shown that children ages 16 months to 4 years rely exclusively on geometric information about the surfaces of a spatial layout (e.g., walls) in order to reorient. Hermer, Spelke and colleagues have shown us that children will not use a geometric pattern of boxes; however they will make use of a distinctively shaped wall. This proves to be the case in rectangular, square and cylindrical enclosures. It is also the case when children are purposely familiarized with the testing environment and its associated landmarks. The degree of familiarity with the environment and landmarks apparently makes little difference to the ability of children to use non-geometric information to reorient and locate displaced objects (Gouteux & Hermer, 2001; Hermer & Spelke 1994; 1996; Wang et al., 1999)

Hermer and Spelke (1994) concluded that their findings indicated the presence of an encapsulated mechanism for reorientation that is based on recognition of the geometric properties of shape – a geometric module. They proposed that their work is suggestive of distant problem solving processes for reorientation and object localization memory tasks (Hermer & Spelke, 1996).

Given the right task, human adults will also use purely geometric information to locate a target, (Pike, 2001). Participants were presented with two black rectangles. One of the rectangles had a stripe down the side of it. Participants were shown targets located in one corner of the rectangle (Spracklin, 2004). The researcher spun the rectangle manually. To distract the participant while the rectangle spun the researcher had them complete math problems out loud. When the rectangle was finished spinning the participant was asked to locate the corner where the target was previously shown. Results indicated that participants were accurate at locating the correct target position with very few rotational errors.

Spracklin designed an experiment to demonstrate that adult humans use a geometric module when no other featural cues are available for locating a target. The rectangles Spracklin used were similar to Pike’s however he presented them on a computer program. The computer program was created to eliminate any confounding variables. For example manually spinning the rectangle had cause for each trial to have rotations that were not always consistent in speed, whereas the computer allows each trial to be exact. Spracklin’s assumption was that when no featural information was available, adult humans would solely rely on geometric information to locate the target. If findings were correct it would confirm that a geometric module does exist in human spatial representation (Spracklin 2004). Results demonstrated that were a significant number of rotational errors (meaning that participants picked the geometrically equivalent corner). Both in the cued (featural information provided) and uncued (no featural information) conditions, a significant number of rotational errors occurred opposed to other incorrect locational error. The results indicate that participants used geometric properties to aid their decision (Spracklin, 2004).

A question still remains that has not been looked at very much. Are there sex differences on spatial tasks? The question is whether any difference in cognitive behaviour between males and females can be attributed to biological differences between the brains of the two sexes was posed by Kolb and Whishaw (1996). Spatial skills, which help people interpret maps and technical drawings, are important to everyday living as well as performing well in school and on the job (Learmonth, Newcombe, & Huttenlocher, 2001). Evidence shows that males outperform females in this area by the time they reach adolescence (Pike 2001). The implicit assumption is that males outperform females on visuospatial tasks. Males must have better spatial memory and perhaps more brain space devoted to this function (Feng et al., 2007). It’s very difficult to pinpoint where theses differences occur. Both males and females are able to solve visuospatial problems and remember spatial locations. As the sexes reach a steady state the differences no longer exist (Feng et al., 2007). Data shows that probe test have revealed that males and females rats use spatial information differently. It appears that males simplify the task by utilizing a single type of distal cue – the shape or global geometry of the test room (Williams et al., 1990a). Females in contrast rely on multiple cues; unlike males they make use of landmarks as well as other distal cues (Williams et al., 1990a).

Rats were injected with neonatal hormones (MC and FNE). Males made fewer errors during acquisition of a radial arm maze task. After the rats reached a steady rate performance no differences were detected. Williams et al believed that the rats were using visual cues to navigate. The assumption made was that if they moved the visual cues around then the rats would be mislead in choice performance and behave in ways as if they were moved to an unfamiliar room (Williams et al., 1990). Results showed that the male rats relied on a single cue of the environment – room geometry. The males were never affected by the removal of the landmark or changes, only by changes in the room shape. The females used two or more cues, landmarks and geometry, in order to locate the target. When the landmarks were rearranged in the environment it disrupted the females' navigation suggesting that the females use multiple cues in combination (Williams et al., 1990).

Janowsky et al., (2002) gave retired men testosterone or a placebo in scrotal patches and found significant improvement in performance of spatial tasks and not in other cognitive measures. Estradiol levels had decreased and were correlated with the improvement in spatial performance. It would not be surprising to find such a difference between males and females given such as spatially loaded task. The present experiment will compare females and males on the Spracklin task.

Methods

Participants

Participants were male and females undergraduate first year students, at Algoma University College ages ranging from 17-25 years.

Apparatus

Participants were tested through the use of a computer program that displayed two white rectangles (10x5 cm). One of the rectangles (used in the cued condition) had a blue strip along one side. The rectangle would rotate on a speed of 8 revolutions per second.

Procedure

Before the experiment each participant was informed that his or her participation was completely voluntary and he or she was free to terminate their participation at any time. Participants were tested individually and seated at a desk in front of a computer monitor. In the corner of the rotating rectangle on the computer monitor was a red dot which faded away after 10 rotations. The students were asked to follow the corner where the red dot was. Once the red dot faded away, participants were asked to click on the corner with the computer mouse, where the red dot had been located. Participants completed a total of 36 trials; with one of the two rectangles being presented; an uncued and cued rectangle (Spraklin, 2003). The cued rectangle was presented first than the cued rectangle. To maintain consistency half of the participants were given the cued conditions first, and the other half of the participants given the uncued first.

After the completion of the experiment participants were thanked for their participation and given a verbal debriefing containing the objectives of the experiment. The entire process took about 15 minutes for each participant.

Results

Both the cued and uncued rectangle conditions significantly had more rotational errors contrasting to other incorrect locations errors. Based on the participation information, the information indicated geometric properties of the rectangle were used to assist in their decisions. This is also what Spracklin, (2003) found in his study. However, in contrasting the males to females, females made more rotational errors contrasting to other locations that are no correct in the uncued task.

Chi-squared analyses was distributed to showed the distribution of choices ($X_2(1) = 3.84$) $p<.05$. There was no significant difference between males and females on the uncued task. Result show that the variance was not great enough and it had occurred from chance. The cued task showed a significant difference in males ($X_2(1) = 30.84$) $p < .05$ and females ($X_2(1) = 42.32$) $p < .05$. This indicated that males perform differently on spatially loaded tasks.

Males

°49	24
20	7 x

Females

°52	15
23	10 x

O = Correct Location

X = Geometric equivalent of correct location

Figure 1. Distribution of responses in cued rectangle condition.

Males

°31	20
28	21 x

Females

°29	20
20	31 x

O = Correct Location

X = Geometric equivalent of correct location

Figure 2. Distribution of responses in the uncued square condition

Discussion

It was hypothesized that when no featural information is available males rely on geometric information to locate a target however, females rely more on featural information to locate a target. The results in this present study indicated that when locating a target on a rectangle, males rely on the geometric properties of the rectangle and females rely on the featural information. The rotational errors indicate that the participants were using metric relations of distance and angles between the rectangle shape and the location of the target. Theses errors are at the correct location but incorrect to the features of the rectangle. In the uncued task there is no sex difference. The result received were no standard, that people show more rotational errors. The interesting results are that the males followed the cue less than the females, showing that males do not rely as much on features as females.

Previous research has shown that adult humans conjoin featural and geometric information in spatial representation (Hermer & Spelke, 1994). Therefore it can now be said that there are sex differences in spatial representation. However, the present research has no gone that far in depth in studying how large the spatial representation differences are. This is a question for future research.

There are numerous directions for future research to take in studying sex differences in human spatial representation. Slowing down the rotational speed of the rectangle may improve participant's performance in choosing the correct location. By slowing the rotation down the participant may be able to focus on the location of the red dot as it fades away. Perhaps varying the size of the rectangle would allow researchers to examine whether the differing sizes of rectangles have an effect on locating the target.

To summarize, the present experiment was used to study sex differences for processing geometric information. Results clearly indicate that males perform differently on spatial loaded tasks. Females rely on featural information and males rely on the geometric properties.

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