12-2-2015

The Effects of Size and Principal Axis Difference Ratio on the Use of Featural and Geometric Cues

Spencer J. Price
Georgia Southern University

The Effects of Size and Principal Axis Difference Ratio on the Use of Featural and Geometric Cues

An Honors Thesis submitted in partial fulfillment of the requirements for Honors in Psychology

By
Spencer Price

Under the mentorship of Kent D. Bodily

ABSTRACT

Enclosure size has been shown to affect an animal's reliance on featural and geometric cues when reorienting in space. Previous research has shown that humans and animals rely primarily on geometric cues in smaller enclosures, and on featural cues in larger enclosures. The multiple-bearings hypothesis predicts that directional information is more discriminable than distance information when landmarks are father away from a goal. As the size of the environment increased, the distance information was less discernible than featural information. In the current study, we tested to see if the reliance on geometry changes across enclosure size. Three different Principal Axis Difference (PAD) Ratios were used to manipulate the salience of the geometric cues across three different enclosure sizes. We predicted that if the PAD ratio was high, then participants would primarily use geometric cues to reorient themselves. The results suggest that PAD ratio manipulations affected participant's reliance on geometric cues, and that participants consistently relied on featural cues when those were present.

Thesis Mentor: ________________

Dr. Kent D. Bodily

Honors Director: ________________

Dr. Steven Engel

Fall 2015
Department of Psychology
University Honors Program
Georgia Southern University

Acknowledgements

I wish to express my deepest gratitude towards my thesis mentor, Professor Kent Bodily, who showed great patience and thorough guidance throughout his mentorship. The wisdom he has passed on will not be forgotten through my future endeavors.

I also owe appreciation to my lab partner, Gregory Sullens, for the time he dedicated to running participants, testing out the virtual environments, and analyzing the data.

I want to thank my parents, Bridget and Mark Price, for the support, both psychologically, and, of course, financially. You two have been remarkably encouraging throughout my time at Georgia Southern University. In addition to my parents, I want to also thank my brother who, as my best friend and loyal drinking buddy, provided the often needed conversational distractions from my academic efforts.

Lastly, I would like to thank Professor Amy Hackney for believing in me enough to introduce me to and recommend me for the Honors Program. Without you, I may have never attempted to complete this thesis.

The Effects of Size and Principal Axis Difference Ratio on the Use of Featural and Geometric Cues

The ability of animals to determine their location in relation to the environment has long been studied. Animals are able to detect cues in their environment to orient themselves to where they are and navigate to where they need to go. For example, rats were put in a rectangular enclosure with four distinct corners (Cheng, 1986). Panels with different visual textures and odors were placed in each corner. In the first experiment, the rats were trained and tested to go to a target location that changed after every trial. The rats, when tested, searched at the correct corner, but also made rotational errors in which they searched at the diagonal corner. Even though both corners were geometrically correct, only the target location, which had distinctive features such as texture and smell, was featurally correct. This finding suggested that the rats relied on the geometry of the enclosure rather than just the arrangement of the features. In the second experiment, the rats were trained and tested to go to a target corner that did not change over trials. The rats located the target corner more often than any other corner, but still occasionally made rotational errors. This second experiment showed that the rats used featural information under some circumstances. In a third experiment the rats were tested in an affine transformation; the corner panels were rotated clockwise on test trials so that the correct featural corner was in a different corner than the correct geometric corners. During testing, the rats searched three corners, the two geometric corners and the corner with the correct feature. A similar pattern of spatial orientation based upon enclosure geometry has been seen in chicks (Vallortigara, Zanforlin & Pasti, 1990) fish (Sovrano, Bisazza &

Vallortigara 2003) pigeons (Kelly, Spetch & Heth, 1998) children (Learmonth, 2002) and adults (Bodily, et. al, 2013).

Principal axes may explain the search errors of the rats mentioned above. In the rectangular environment with distinct features in each corner, the goal location was unambiguous when using the features. However, if the features are removed and only the shape of the environment is left for the rat to reorient, then the corner is ambiguous. The correct corner and the corner diagonal to it in the rectangle are indistinguishable. The search errors made by the rats to the diagonal (rotationally equivalent) corners suggests that they learned about the geometry of the space. Principal axes run through the centroid (i.e., center of mass) of the shape; for a rectangle the major principal axis runs lengthwise and the minor axis runs widthwise (for a more detailed explanation, see Cheng, 2005). The axes do not take into account any features of the environment, only the shape. The rats' search behavior can be explained by the rats finding the principal axes, moving up or down the major principal axis, and then either turning left or right to the target corner depending on their training. If the rats followed the major principal axis to navigate, either corner would be geometrically correct.

Research has shown that geometric cues primarily guide behavior in small enclosures, but featural cues, such as color patterns, landmarks, and smells, primarily guide behavior in large enclosures. Children were put in either a large or small enclosure with a landmark and shown the location of a target corner (Learmonth 2002). Children under the age of six used the landmark to navigate to the correct corner in the large enclosure, but not in the small enclosure suggesting they used featural cues in the large enclosures to navigate. Chicks trained in a small or large room with four distinct features in each corner could conjoin both geometric and featural cues to navigate to the correct corner for either size (Vallortigara, Fergulio & Sovrano 2005). When tested using an affine transformation the chicks relied more on geometry in the small enclosure and more on features in the large enclosure. In another study, chicks were tested in a large and small enclosure with a blue wall to distinguish the corners; when the blue wall switched locations the chicks in the large enclosure searched in the location consistent with features, and in the small enclosure they searched in the location consistent with geometry (Sovrano & Vallortigara 2006). Chicks that were trained in the small room with distinctive panels and tested in the small room without the distinctive panels learned the geometry more so than the chicks that were trained in a large room with distinctive panels that were tested in a large room without distinctive panels (Chiandetti et al 2007). A second experiment of the same nature showed that when chicks were tested in a square with features, the chicks in the large group showed more retention of the features than the chicks in the small group. In an experiment done with humans that were also trained and tested in either a small or large room, human adults also searched in the correct featural corners in the large room and in the correct geometric corners in the small room when the cues were at a conflict (Ratliff & Newcombe 2007).

Why enclosure size affects the use of features and geometry to reorient remains an open question. The principal axis account does not predict that enclosure size would affect the use of geometric cues. However, the effects of distance between objects have been found in a related literature on landmark use in foraging. Nutcrackers store food during the fall in large numbers of cache sites, and recover the food during the winter and spring (Gibson & Kamil 2009). The multiple-bearings hypothesis predicts distance error will increase as the distance from the landmark to the goal increases and that directional error will remain constant, that increasing the number of landmarks will allow for an increase in the accuracy of searches, and that the geometric relations between landmarks and a goal will predict the extent to which search accuracy will be increased (Kamil & Cheng 2001). Supporting evidence of the multiple-bearings hypothesis has been shown in nutcrackers (Kamil & Jones 2000) and humans (Forloines, Bodily & Sturz 2015) regarding that directional information results in less error than distal information when encoding the geometry of an array of landmarks. Distal information loses weight as the distance of a landmark increases, however the directional information maintains its weight (Kamil & Jones 2000). If the reliability of distal information decreases as the distance of the landmark increases, then the reliability of encoding for the proper principal axes decreases as the size of the environment increases. The change in the reliability of geometric information could explain why there is a difference in the types of cues that are used primarily in small and large environments.

We propose that the use of geometric cues primarily in small environments and the use of featural cues primarily in large environments is due to the reliability of the geometric information changing across the environment sizes. In the small environment, the distances from walls and landmarks are short, therefore the reliability of the distal information is still high. However, when the environment is large, the distances from walls and other landmarks are large, therefore the reliability of the distal information is relatively low. If the reliability of the geometric information drops below the reliability of the featural information, then the animal will primarily use the more reliable featural information to navigate.

In the current study we manipulated the reliability of the geometric information by changing the Principal Axis Difference (PAD) ratio across three different sized environments. The PAD ratio is the length of the major principal axis (long wall) subtracted by the length of the minor principal axis (short wall), then divided by the length of the major principal axis (long wall) (Sturz & Bodily, 2011). A rectangle with a PAD ratio that is close to zero will have sides that are close to being equal in length and will resemble a square. A PAD ratio that is close to one will have the length of sides more differentiated and will resemble a longer rectangle. When the PAD ratio is high, the ability for participants to disambiguate the geometry of the environment is easy, making it a salient cue for navigation. However when the PAD ratio is low, the ability to disambiguate the geometry of the environment is difficult, making it less salient. Participants in rectangles with three different PAD ratios were tested in an affine transformation across three separate sizes. Previous evidence suggests that participants will choose the corner with the correct featural information in large environments, and will choose the corner with the correct geometric information in the small environments. However, if the reliability of the geometry causes the change in navigational behavior across sizes, then participants' choices to the correct geometric corners should increase when the PAD ratio is high, even in a large environment. Likewise, the participants' choices to the correct geometric corners should decrease when the PAD ratio is low, even in a small environment. In addition to the affine tests, participants were also tested in an all geometry enclosure in which all four of the boxes were not distinct. The trials tested if the participants were learning geometry in the training trials. The participants should be able to choose the select the correct geometric corners regardless of the size of PAD ratio of the enclosure. However, the participants in the .75 PAD ratio group should choose the geometric corners during the geometry test more frequently than the .50 or .25 groups because the geometry of the enclosure should be more salient. The participants in the .25 PAD ratio group should choose the geometric corners during the geometry test less frequently than the .50 or .75 groups because the geometry of the enclosure should be less salient.

Method

Participants

The participants of this study were seventy-two undergraduate students (36 male and 36 female). The participants were either given extra credit or were completing a requirement for a course in Psychology in exchange for their participation. All participants signed an informed consent.

Apparatus

A three-dimensional virtual environment was used to train and test the participants. The virtual environment was created using the Valve Hammer Editor and run on the Half-Life Team Fortress Classic platform. A desktop computer with a single 21 inch LCD monitor was used to display the environment, and a gamepad with joysticks was used to interact in the environment. The left joystick allowed the user to aim, and two buttons on the right of the gamepad allowed the user to make a selection. Speakers were set to 60 decibels. The selections made by the participant and other data were collected using the Half-Life Dedicated Server on a separate computer.

Stimuli

Nine different rectangular environments were used in the virtual environment. The rectangles were categorized according to the PAD ratio and the length of the shortest wall. There were three distinct PAD ratios that were used (.25, .50, and .75). Three different lengths of the shortest walls were used for each PAD ratio (3.5 m, 14 m, and 28 m). The dimensions for the group with PAD ratios of .25 were 3.5 m x 4.67 m, 14 m x 18.67 m, and 28 m x 37.33 m. The dimensions for the group with PAD ratios of .50 were 3.5 m x 7 m, 14 m x 28 m, and 28 m x 56 m. The dimensions for the group with PAD ratios of .75 were 3.5 m x 14 m, 14 m x 56 m, and 28 m x 112 m. The height of the walls at eye level (1.6 m) with the participant's virtual perspective, and the ceiling was 6.6 m.

Each of the rectangles contained boxes located in the corners that served as targets for the participant to make his/her selection. The boxes were blue, green, brown and yellow and had a different pattern for each of the three short wall lengths conditions within each PAD ratio (see figure 1). Each participant would not see the same box pattern for two different rectangles. In the geometry testing trial types the boxes were white with a silhouette that resembled a target practice figure. The boxes were all the same height across all of the sizes. They boxes did not change locations during training trials. Each box moved clockwise one corner for the affine trials. This setup paired the featural cues and geometric cues against each other.

Figure 1. Top picture shows player facing two distinct beacons and laser gun used to shoot the boxes. Bottom picture shows player facing two indistinct beacons for the geometry tests, and a laser gun.

The participants used a virtual laser gun to select boxes (see figure 1). The laser gun emitted a green beam of light. The participants could not move forward, backward, or sideways, but rotated using the joystick.

Procedure

Participants were told to move through all of the levels to complete the experiment using the gamepad. Instruction was given that the left joystick would change where the laser gun pointed, and the two buttons on the right would fire the gun. Firing at the correct box would move the participant forward to the next level. Firing at the correct box resulted in a white flash and auditory feedback in the form of a bell followed by a seven second black screen to indicate a new level.

Participants were randomly assigned to one of three PAD ratios with one of the six possible orders of the three different wall length conditions. Each participant underwent six training trials to learn to select a target box per condition. The participants had to shoot the laser gun at the target box to move on to the next trial. The boxes did not change corners throughout any of the training trials. The boxes did change design across all three wall length conditions. The participants were began the trial in the center of the rectangle facing either north, south, east, or west.

There were six testing trials that each came up in a block with three training trials. The order that the testing trial came up in each block was random. Three of the testing trials were an affine transformation in which each box moved to the corner that was clockwise to it. This provided a cue conflict in which the features of the boxes were paired against the geometry of the rectangle compared to training. The other three testing trials tested if the geometry was learned. The boxes were non-distinct in these trials. Only one selection was made and there was no auditory feedback for a selection in testing trials.

Results

Training

A three-way mixed analysis of variance (ANOVA) was used to analyze the mean proportion of correct first choices by PAD ratio (.25, .50, and .75) and sex (male and female) across blocks (1-3), and revealed only a main effect of block $F(2, 132) = 14.339$, $p < .001$ for the 3.5 m training enclosure. The participants in the 3.5 m enclosure were able to learn to select the correct corner. There was only a main effect of block $F(2, 132) = 63.780$, $p < .001$ for the 7 m training enclosure. The participants in 7 m enclosure were able to learn to select the correct corner. There was only a main effect of block $F(2, 132) = 41.158$, $p < .001$ for the 28 m training enclosure. The participants in the 28 m enclosure were able to learn to select the correct corner.

Geometry testing

A three-way mixed analysis of variance (ANOVA) was used to analyze the geometrically correct responses for each PAD ratio (.25, .50, .75) and sex (male and female) across enclosure size (3.5 m, 7 m, 28 m) in the geometry test, and revealed only a main effect of PAD ratio $F(2, 70) = 3.410$, $p < .05$. There were no other main effects or interactions *ps* $< .05$. As shown in Figure 2, responses to the geometrically correct corners differed between PAD ratios, but not across enclosure size.

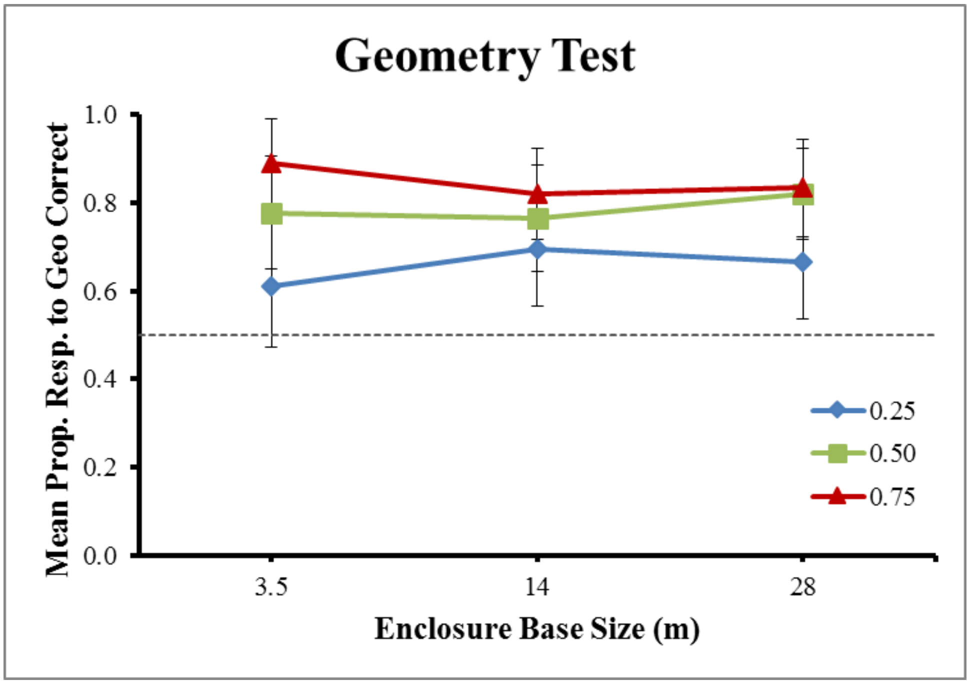

Figure 2. The graph shows mean proportion of responses to correct geometric corners for each PAD ratio across enclosure size for the geometry tests.

Affine testing

A three-way mixed analysis of variance (ANOVA) was used to analyze the geometrically correct responses for each PAD ratio (.25, .50, .75) and sex (male and female) across enclosure size (3.5 m, 7 m, 28 m) in the affine test, and revealed no main effects or interactions for PAD ratio, sex, or size. As shown in Figure 3, responses to the geometrically correct corners did not differ between PAD ratios or enclosure sizes.

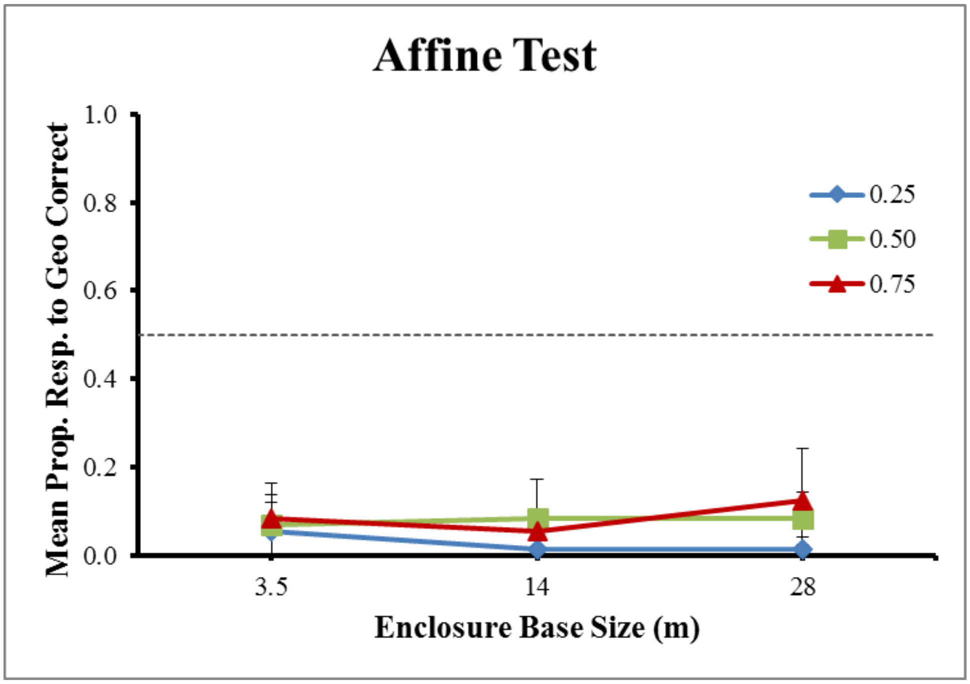

Figure 3. The graph shows mean proportion of responses to correct geometric corners for each PAD ratio across enclosure size for the affine tests.

Discussion

The participants were able to learn to select the correct corner in all three sizes. The sex of the participants and the size had no effect on the frequency at which the participants chose the geometric corners as their first response on the geometry test trials. The .75 PAD ratio group selected the geometrically correct corners more often in the geometry test trials than the .25 PAD ratio group. The PAD ratio, sex, and size of the enclosure did not affect which corner the participants chose during the affine tests.

Participants choosing the geometric corners in the .75 PAD ratio group more often than the .25 group is consistent with previous research that says the geometry should be more salient with PAD ratios that are close to one. Participants choosing the geometric corners in the .25 PAD ratio groups less than the .75 group is also consistent with previous research that says the geometry should be less salient with PAD ratios that are close to zero.

We predicted that participants' choices to the geometric corners would increase if they were in the .75 PAD ratio group for the affine tests in the large enclosure. We also predicted that participants' choices to the geometric corners would decrease if they were in the .25 PAD ratio group for the affine tests in the small enclosure. The evidence did not support either of the predictions. The evidence also did not support previous research that participants in small enclosure should select the geometric corners more often than participants in large enclosures.

Previous research suggested that geometry is primarily used in small enclosures, and features are primarily used in large enclosures. The results of the current study do not support the effect of enclosure size on the use of geometric and featural cues. One possible reason for why the participants chose to primarily select the corners with the correct features in the affine test is that there was an overpowering reliability of the features during training. The participants were trained to select one out of the four corners, however there were two possible geometrically correct corners. One of those corners was always an incorrect selection. If the participants had learned to select the correct geometric corner, then they would have made an incorrect selection half of the time during training trials, However, if they learned to select the correct featural corner, they would never make an incorrect selection. This may explain why participants relied so heavily on the featural cues during the affine test trials.

Future research should examine the effects of a more balanced experimental design with regard to the reliability of the geometric and featural cues. Using only two distinct featural cues may adequately balance out the relative reliability of geometric and featural cues. One pair of cues would be at the geometrically correct corners, while the second pair of cues would be at the geometrically incorrect corners. The target location could be both corners since they are identical. Either of the target corners would be both geometrically and featurally correct. This may serve to balance out the reliability of both of the cues. When the reliability of both of the cues is balanced, a change in the reliance of the geometric and featural cues would be more likely detected across enclosure size and PAD ratio manipulations during the affine tests.

References

Bodily, et. al. (2013). Beacons and surface features differentially influence human reliance on global and geometric cues when reorienting in a virtual environment. *Behavioral Processes, 93,* 71-81.

Cheng, K. (1986). A purely geometric module in the rat's spatial representation. *Cognition*, *23,* 149-178.

Chiandetti, C., et. al. (2007). Spatial reorientation: The effects of space size on the encoding of landmark and geometry information. *Animal Cognition, 10,* 159-168.

Forloines, M. R., Bodily, K. D., & Sturz, B. R. (2015). Evidence consistent with the multiple-bearings hypothesis from human virtual landmark-based navigation. *Frontiers in Psychology, 6*.

Gibson, B., & Kamil, A. (2009). The synthetic approach to the study of spatial memory: Have we properly addressed Tinbergen's "four questions"? *Behavioural Processes, 80,* 278-287.

Kamil, A. C., & Cheng, K. (2001). Way-finding and landmarks: The multiple bearings hypothesis. *Journal of Experimental Biology, 2043,* 103-113.

Kamil, A. C., & Jones, J. E. (2000). Geometric rule learning by Clark's nutcrackers (*Nucifraga columbiana*). *Journal of Experimental Psychology: Animal Processes, 26*(4), 439-453.

Kelly, D. M., Spetch, M. L., & Heth, C. D. (1998). Pigeons' encoding of geometric and featural properties of a spatial environment. *Journal of Comparative Psychology, 112*, 259-269.

Learmonth, A. E., Nadel, L., & Newcombe, N. S. (2002). Children's use of landmarks: Implications of modularity theory. *Psychological Science, 13* (4), 337-341.

Ratliff, K. R., & Newcombe, N. S. (2007). A matter of trust: When landmark and geometry are used during reorientation.

Vallortigara, G., Zanforlin, M., & Pasti, G. (1990). Geometric modules in animals' spatial representations: A test with chicks (*Gallus gallus domesticus*). *Journal of Comaparative Psychology, 104,* 248-254.

Sovrano, V. A., Bisazza, A., & Vallortigara, G. (2003). Modularity as a fish (*Xenotoca eiseni*) views it: Conjoing geometric and nongeometric information for spatial reorientation. *Journal of Experimental Psychology: Animal Behavior Processes, 29*, 199-210.

Sovrano, V. A., & Vallortigara, G. (2006). Dissecting the geometric module. A sense linkage for metric and landmark information in animals' spatial reorientation. *Psychological Science, 17(*7), 616-621.

Sturz, B. R., & Bodily, K. D. (2011). Is surface-based orientation influenced by a proportional relationship of shape parameters? *Psychonomic Bulletin and Review.*

Vallortigara, G., Fergulio, M., & Sovrano, V. A., (2005). Reorientation by geometric and landmark information in environments of different size. *Developmental Science, 8*(5), 393-401.