Orientation Effects: Was Rock Correct?

An Honors Thesis (ID 499)

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There is still great debate about how humans recognize and perceive objects. One problem is how objects viewed in unfamiliar orientations are recognized. Although the features are physically identical in an object presented upside down, sometimes recognition is disrupted or does not even occur. The most influential theory to explain recognition failure is Rock's "frame of reference" theory (1973, 1983). He contends that shape perception is dependent upon a perceptual reference frame. Rock argues that within this reference frame, the top-bottom axis is the most important, and that the front-back and left-right axes are of secondary importance. If an object is presented in a novel orientation and the wrong part is labelled as top, recognition may not occur.

This theory was recently examined by Rock, DiVita, and Barbeito (1981). In these experiments, wire figures were first presented in either a frontal or sagittal viewpoint. Then these wire figures were rotated 0, 90, and 180 degrees around all three axes and tested for recognition to the frontal or sagittal viewpoint first seen. Their results supported their hypothesis that the top-bottom axis is the most salient of the three axes. However, they also found an effect of the front-back axis, which was not expected. They had hypothesized that there would be no drop in recognition for the 90 degree rotation about the vertical axis because there was no change in the top-bottom of the figure. Rock, DiVita, and Barbeito attributed this to retinal changes which caused the subjects to give a different egocentric description than they had given to the original wire figures.

There are a number of problems with Rock, et al's (1981) research. One criticism is the choice of figures used. These figures were made of twisted wire. It can be argued that these wire shapes are not very representative of real world objects. There is also the tendency to have reversals when working with wire figures. A second criticism is that the experiments only used rotations of 0, 90, and 180 degrees. In other words, for vertical axis rotations, subjects saw the exact same wire figures (0 degrees), wire figures that were mirror images of the original (180 degrees), and one orientation that was half way between the two (90 degrees). This sampling of rotations may not be very representative. Note that it was in the 90 degree rotated stimulus that the unexpected significant result was found. A third criticism is that it is not clear if Rock's figures were shown in the best possible orientation. The particular views of objects used may affect the perceived features of the objects and thus the perceived shape. For example, Jones and Butler (1988) found that nearly rectangular solids can appear rhomboidal in certain orientations. Because Rock only placed his wire figures in a "frontal" or "sagittal" viewpoint, it cannot be assured that his figures were being viewed from a point of view that appropriately represented the shapes.

The purpose of the present study is to provide a stronger test of Rock's hypotheses. First, solid objects will be used. Solid objects will eliminate the problems of reversals which wire objects encounter. Also, solid objects are more representative of real world objects and thus are more ecologically valid. These solid objects will have no regularities (e.g., parallel lines, right angles, or symmetries) which could resist possible orientation effects. Second, these solid objects will be placed in canonical positions (defined as a view that appears to be a good description/illustration/portrayal of the object) to eliminate possible problems caused by poor viewpoints. Third, more rotations across all three axes will be used than have been used in previous research. The use of many rotations should provide more power for testing effects of axes of the reference frame.

Method

Subjects

The 55 subjects that participated in this experiment were obtained from the Ball State University Department of Psychological Sciences Research Participant's Pool. These subjects were divided into two groups. Group 1 contained 37 subjects and Group 2 contained 18 subjects.

Apparatus

Four Apple II computers were used. Three of these computers had green screen monitors and one had a black and white screen monitor. Special software was written specifically for this experiment in Basic and Machine language. The program presented stimuli and stored the subjects' data.

Stimuli

One very irregular 3-D object was created (shown in Figure 1). It has six sides. Each side is an irregular quadrilateral surface and each surface is different from the others. Also, there are no regularities between the surfaces. This object was positioned in two separate canonical positions, A and B as shown in Figure 1. The canonical views were chosen by a group of judges and all judges agreed that the views represented canonical positions of the object.

The two groups of subjects saw different canonical views as their standard stimulus. Group 1 saw A and Group 2 saw B as depicted in Figure 1. Stimuli to be compared to the standards were created by rotating the the standards around the X (left-right), Y (top-bottom), and Z (front-back) axes. Standards were rotated by 45, 90, 135, 180, 225, 270, 315 degrees. Group 2 also saw one stimulus rotated by 0 degrees.

Procedure

Subjects were given written instructions informing them about the task that they would be completing. They were told that they would be comparing the similarity between drawings of objects. The subjects were instructed that they would first see a drawing of an object then after a brief time a second drawing would appear. They were asked to compare the second object to the first on a scale ranging from one to seven, one meaning that the objects are extremely different and seven meaning that the objects are really the same. Subjects were also told that drawings of the same object drawn from different viewpoints may look very different, so they should not just compare the drawings but compare the objects that the drawings represent. In addition, subjects were asked not to tilt their heads when viewing the objects, but to look at the objects with their heads held vertically.

After subjects had read the instructions, they were taken to a common computer which was similar to the computer that they would be working on. At this computer they were shown its basic features, including the number keys 1-7 and a reminder card located under the screen which had the rating scale on it. After all questions were answered, subjects were taken to an individual space in which they were to complete the experiment on the designated computer.

All subjects judged all 21 (Group 1) or 22 (Group 2) stimuli three times in blocks for a total of 63 or 66 judgments. Order of stimuli was randomized independently for each subject for each block of stimuli. The data collected from the second and third repetitions were used for interpretation. Judgments of the 0 degree rotation were evaluated independently of the other rotations.

Results

Judgments of the 0 degree rotation indicate that subjects judged the identity correctly in almost all trials. An ANOVA was run on the 0 degree rotation stimuli using the three repetitions as the independent variable. Results revealed no significant effect of the repetitions [$F(2,34)=0.00$, n.s.]. The mean was 6.89 for all three repetitions. Results indicate that 6.89 is not significantly different from the maximum judgment of 7.00 [$F(1,17)=1.42$, n.s.].

The results found do not support Rock's hypothesis that the top-bottom axis is the most important rather they suggest that the front-back axis is most important. An ANOVA was calculated on all other stimuli using group, axis, and degree of rotation as independent variables. A highly significant three-way interaction was found among axes, degrees rotated, and group [$F(12,420)= 6.88$, $p<.0001$, $eta^2=1.6\%$]. This interaction is shown in Figure 2. As can be seen in Figure 2, generally, rotations about the Z axis (front-back) result in higher similarity judgments than rotations about the X axis (left-right) or Y axis (top-bottom). This result is inconsistent with Rock's theory. There were several other significant effects related to the three-way interaction. Powerful main effects of axes were found [$F(2,70)= 224.66$, $p<.0001$, $eta^2=48.6\%$] along with a significant main effect of degrees rotated [$F(6,210)=6.52$, $p<.0001$, $eta^2= .9\%$]. A significant interaction was also found among axes and degrees rotated [$F(12,420)=7.82$, $p<.0001$, $eta^2=1.85\%$]. Note that the strongest effects were found for axes. Repetition of the stimuli did not effect the judgments. No interaction or main effects were found for repetition.

The data does support the hypothesis that the Y axis (top-bottom) is somewhat important. This is found by eliminating the effects of the front-back axis in the data. If the front-back axis was the only important axis, then rotations around X and Y would affect the front equally and rotations around the Z axis would be the same as the identity condition (i.e., 6.89). However, rotations around the axes are: 2.94 for the X axis, 3.13 for the Y axis, and 6.38 for the Z axis. This shows that the mean judgments for the stimuli rotated about the X axis are .31 lower than those for the Y axis and those for the Z axis are .52 lower than the identity condition. Together, these findings clearly show a small effect of the top-bottom axis.

Discussion

The overall results strongly contradict Rock's (1973, 1983) hypothesis that the top-bottom axis of the frame of reference was the most important. Instead, these results show that the front-back axis is most important. Interestingly, this finding explains Rock, DiVita, and Barbeito's (1981) unexpected significant result in the front-back axis for the 90 degree rotation.

One important difference in the two experiments is that Rock, DiVita, and Barbeito used wire objects whereas solid objects were used in this experiment. The use of solid objects eliminated the problem of possible reversals which were inherent in Rock's wire figures. A second critique of Rock's wire objects was that they are not representative of real world objects. The majority of objects that can be found in the world are solids where edges that are behind the particular object are hidden from the observer. This allows observers to see the hidden parts of the object only if they reorient themselves in a manner that reveals the hidden parts. The objects used in this experiment were solid and representative of objects found in the real world and are more ecologically valid than those of Rock, DiVita, and Barbeito.

The procedures for portraying the objects in this experiment also simulated real world objects better than those of Rock's. The above experiment used many more rotations than did Rock, DiVita, and Barbeito's study. As mentioned above, people orient themselves in many positions to view their world, not only in 0, 90, and 180 degree increments. By rotating the objects every 45 degrees, the results found in the above study are more representative of the different orientations that could be found in real life.

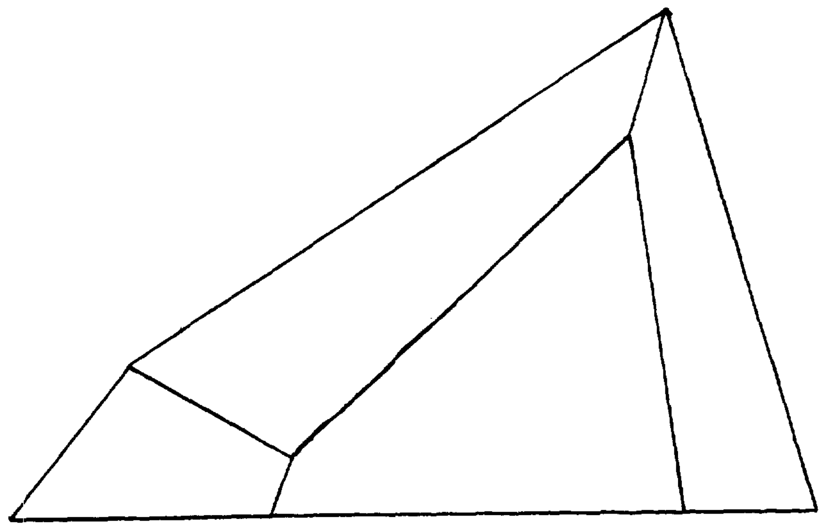
Another variable that may explain some of the different results obtained in the present study and Rock et al's (1981) study has to do with positions used to portray the stimuli.

It was suggested in Jones and Butler (1988) that objects can be easily misinterpreted if placed in a view that is not representative of the object. The example used in the article was a nearly rectangular solid that was placed in a view that caused it to be perceived as a rhomboid. The above experiment placed the objects in reported canonical positions that illustrated the objects well, whereas Rock, DiVita, and Barbeito used wire objects that were placed from a frontal or sagittal viewpoint, which may not necessarily be canonical.

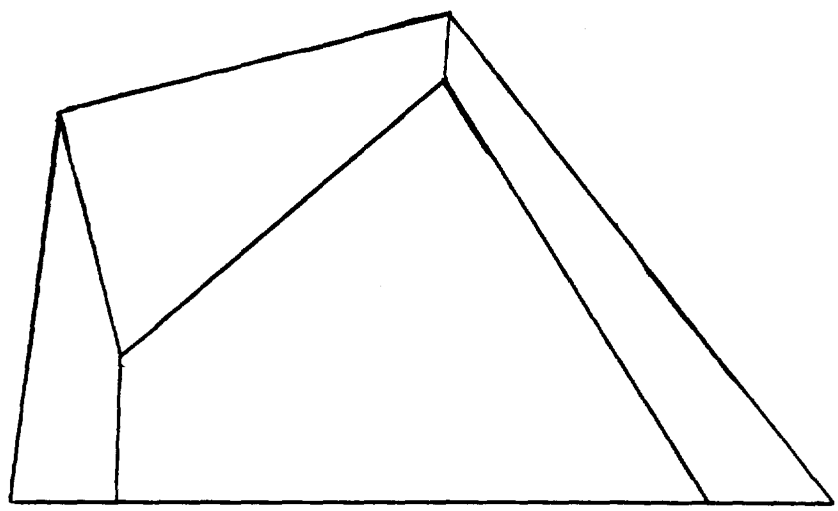
The last variable that could have minimized the effects of the depth axis in Rock, DiVita, and Barbeito's study is regularity. They only oriented their figures from frontal and sagittal viewpoints whereas in the above experiment great care was taken to choose objects without any regularity and to orient them in a canonical position. In similar past experiments done by the author, it is beginning to appear that regularity in objects can minimize the effects of orientation. This is also supported by a study done by Butler and Kring (1987) where parallel lines was shown to have a strong effect on the perception of 90 degree angles in drawings of objects. It appears that regularity has an effect on perception, but to what extent is not yet known.

From the above results, this author would like to make the argument that the explanation given by Rock for the low recognition of the 90 degree rotation around the depth axis is incorrect. Rock argued that retinal changes caused subjects to give that particular rotation a different egocentric description than had the original positions of the wire figures. In the data given above, it is sensible to realize that not all of the results found was caused by a single retinal change. Another explanation is that the results obtained by Rock occurred as a result of the strength of disruption that the depth axis caused. This may not have been clear to Rock, DiVita and Barbeito because of the above criticisms on their study. The results obtained from the present study seem to support this alternate explanation.

The author encourages others to replicate this experiment in order for the above explanations to be validated. Replication is also encouraged because the data found in this experiment appears to be in contrast to previous results found by Rock. In addition replication is encouraged because this is the first reported concrete indication of the front-back axis being of primary importance. Replication should include objects that are both similar to those used in this experiment and ones that are different in order to make the results more generalizable than those found in this experiment. In addition to simple replication, another question that should be investigated is to what extent does regularity minimize the effects of orientation.



Position A



Position B

Figure 1. Canonical positions A and B of object.

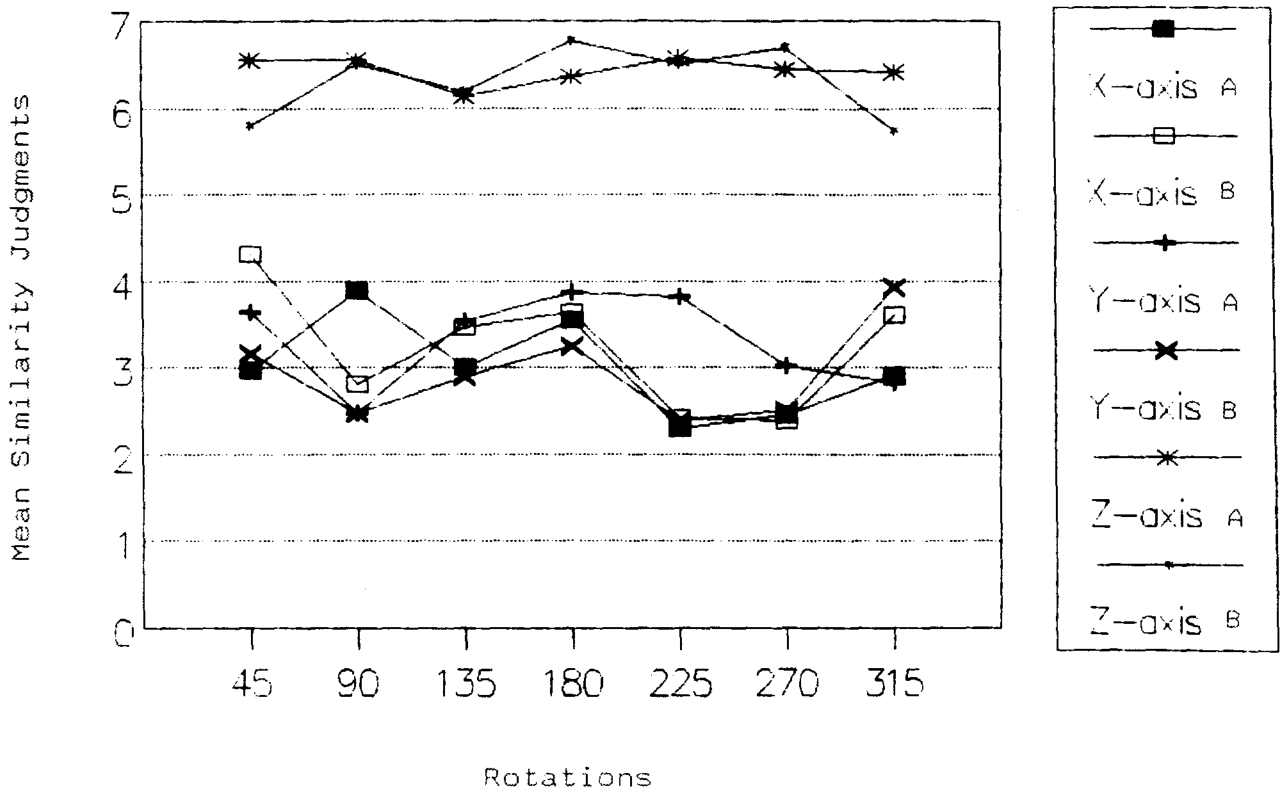


Figure 2. Three-way interaction found among axes, degrees rotated, and group.

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