Developmental Trends in Object Recognition from Preschool to Adolescence: A Preliminary Investigation

This experiment attempts to determine developmental trends in object recognition. Two object identification questionnaires were administered to 26 children between the ages of 4 and 10. One questionnaire included pictures fragmented arbitrarily, whereas the other included pictures fragmented according to recognition-by-components (RBC) theory (Biederman, 1987). Factors related to performance on the questionnaires were measured using the Test of Nonverbal Intelligence (Brown, Sherbenou, & Johnson, 1990) and the Figure-Ground, Form Constancy, Closure, and Spatial Relations subtests of the Developmental Test of Visual Perception (DTVP; Hammill, Pearson, & Voress, 1993). There was a significant increase in the number of correctly identified objects with age for the arbitrarily fragmented objects, but not for the RBC objects. This finding suggests that the RBC objects contained sufficient information for identification across ages. In addition, different factors appear to influence recognition between the two types of objects. Arbitrarily fragmented objects are related to visual closure ability whereas RBC objects are related to the total of the four DTVP-2 subtests. These findings suggest that recognizing arbitrarily fragmented objects may be influenced by a specific perceptual ability but the RBC objects may be influenced by a number of related abilities.

Recognition-by-components (RBC) theory (Biederman, 1987) suggests that visual stimuli are composed of geons. Geons are conical components derived from contrasts of five readily detectable properties in a two-dimensional image. The ability to detect these properties normally does not vary even when the image is viewed from a different position or when the quality of the image changes. Biederman’s (1987) model includes 24 geons that form a visual alphabet. The same geons when combined differently form different objects.

RBC theory provides a relation between the principles of perceptual organization and pattern recognition. A complex object is composed of simple geons and is identified by the individual geons. If object perception is based on the components and the components can be recovered, then the object should be recognizable. Objects that have been degraded are recognizable if two or three geons can be recovered.

Biederman (1987) suggests that detecting edges, using the edges to form geons, and then using the geons to construct simple and complex objects are fundamental processes of object perception. Because geon detection is a fundamental process, it is hypothesized to occur early in both the temporal and developmental processing of objects. Therefore, detecting geons is one of the first processes completed when we look at an object. From a developmental perspective, detecting geons is one of the earliest visual processes in which we engage.

Little research has been conducted regarding developmental trends in object recognition, particularly research that incorporates RBC theory. Murray and Kinnison (1989) found that younger children, compared to older children, required more of an object to be present in order to identify it. However, this study did not fragment pictures according to RBC theory. Frazier and Hoyer (1992) used pictures fragmented according to RBC theory; however, they tested elderly participants. Kohlmeyer, Abbey, Schmidt, Gobell, and Koch (1995) tested children of different ages using pictures fragmented according to RBC theory and found the number of objects recognized increased with age. This study determined that closure is the most important factor for object recognition when the objects are fragmented arbitrarily, and that objects fragmented according to RBC theory appear to be recognizable after a minimal level of visual perceptual development is attained.
The present study examined developmental differences on an object recognition task for participants between the ages of 4 and 10 and also explored differences in factors related to object recognition. It was anticipated that pictures fragmented according to RBC theory would be easier to recognize across ages compared to pictures arbitrarily fragmented.

Method
Participants
Twenty-six children (8 girls, 18 boys) from a rural community in the Pacific Northwest participated in the study. All participants had normal or corrected-to-normal vision. Ages ranged from 4 to 10. Parents were informed about the nature of the study and signed consent forms on behalf of their children.

Materials
Two versions of object recognition questionnaires were developed using 32 pictures selected from the Snodgrass and Corwin (1988) database. Pictures in this database were fragmented according to the Snodgrass, Smith, Feenan, and Corwin (1987) algorithm which deletes parts of a picture falling within a specific pixel region without regard to the types of information being deleted. Sixteen pictures were used to construct the “arbitrary” fragmentation condition using the presentation format of the SOI-LA (structure of intellect learning abilities) test (Meeker, Meeker, & Roid, 1985). An additional 16 pictures, matched for similar features, were used to create the RBC condition. However, pictures in the RBC condition had midsegments removed and vertices extended to control for contour deletion across stimulus conditions.

Nonverbal intelligence was assessed using the Test of Nonverbal Intelligence (TONI-2; Brown, Sherbenou, & Johnson, 1990). The TONI-2 is a language-free and motor-reduced test designed to examine aspects of intelligence unrelated to language. In this test, a series of figures is presented, and each series contains a missing figure. The participant is required to select a figure, from a list of possible figures, that completes the sequence. Therefore, the TONI-2 exploits matching skills and the use of analogies to solve problems.

Other factors related to object recognition were examined using the Figure-Ground, Space Relations, Closure, and Form Constancy subtests of the Developmental Test of Visual Perception (DTVP-2; Hammill, Pearson, & Voress, 1993). The Figure-Ground subtest is a high-level discrimination task used to determine whether or not participants can recognize relevant information and discard irrelevant information. The Spatial Relations subtest involves perceiving a pattern and generating a response consistent with that perception. Visual Closure draws on the ability to recognize familiar objects even when the objects have missing pieces of information. Finally, Form Constancy requires participants to recognize objects regardless of size, position, texture, color, and shading. The TONI-2 and subtests of the DTVP-2 were chosen because nonverbal intelligence and perceptual skills (such as closure and form constancy) appear to be critical for identifying fragmented objects.

Design
The number of correctly identified pictures for each version of the object recognition questionnaires served as the dependent variable. Nonverbal intelligence and developmental level of perceptual ability served as participant variables. Because each participant received both versions of the object recognition questionnaire and the TONI-2 and DTVP-2, a within-subject design was employed.

Procedure
The two object recognition questionnaires were administered in random order across participants. Each participant was given 3 min to correctly identify the 16 objects in each questionnaire. The participants were then administered the TONI-2 followed by the subtests of the DTVP-2. During debriefing, participants were told that the researcher was examining factors that contributed to object recognition.

Results
The average number of pictures correctly identified across ages for the RBC version was 6.61 ($SD = 3.02$) whereas a mean of 5.07 ($SD = 3.07$) was recorded for the “arbitrary” version. Therefore, participants, on average, correctly identified 1.60 more RBC pictures than Snodgrass pictures. A repeated measures $t$ test revealed that this difference was significant $t(25) = 2.77, p < .01$. This finding is consistent with the hypothesis that the RBC pictures would be correctly identified more often than arbitrarily fragmented pictures because the RBC pictures would contain more of the vertices information critical for geon recognition.

Developmental trends in object recognition were examined with two one-way ANOVAs. The number of correctly identified objects served as the dependent variable and age was the independent variable. Results showed a significant age effect for the Snodgrass version, $F(6, 19) = 3.97, p < .01$, but not for the RBC version; older participants correctly identified more objects than did younger participants.
using the Snodgrass version (these trends are presented in Figure 1), but not the RBC version. These findings are consistent with the hypothesis that geons are critical for object recognition. Performance in the object recognition task was invariant across ages for the RBC version, suggesting that younger participants were equally able to use information about the vertices as were older participants. However, older participants were better at identifying pictures fragmented arbitrarily than younger participants. This latter result suggests that the older participants have either learned how to identify pictures fragmented arbitrarily or have gained the cognitive capacity to do so.

Finally, factors affecting object recognition were examined using separate stepwise regression analyses for each version of fragmented objects. The number of correctly identified objects served as the dependent variable. The TONI-2 scores and the four subscores from the DTVP-2 served as factors in the regression analyses. For the RBC version, the total of the four DTVP-2 subtests was the only significant predictor, \( F(1, 24) = 23.92, p < .0001; R^2 = .50 \). This result suggests a minimal developmental level of perceptual ability is needed in order to identify objects fragmented according to RBC theory. For the Snodgrass version, scores from the Visual Closure subtest of the DTVP-2 served as the best predictor for object recognition \( F(1, 24) = 20.07, p < .0002; R^2 = .46 \). Because the Visual Closure subtest includes partially deleted objects, this finding suggests participants’ ability to recognize arbitrarily fragmented objects is simply dependent upon their ability to recognize fragmented objects. Further, it appears that this ability increases with age.

**Discussion**

The results show that the number of objects recognized increases with age for the arbitrarily fragmented pictures. For the RBC version, the number of pictures correctly identified does not differ significantly across ages. These findings correspond with Biederman’s (1987) view that visual processing of geons occurs early in development. Thus both the younger and older children were able to recognize the RBC objects because geon information was recoverable. However, geon information was not always recoverable in the arbitrarily fragmented...
objects, making these pictures more difficult to recognize. However, with age comes experience and exposure to visual stimuli in various situations. When we see a partially occluded object in an everyday setting, geon information may be present or may be obscured. Therefore, the ability to recognize arbitrarily fragmented objects increases with age.

Ability to recognize arbitrarily fragmented objects was related to scores on the Visual Closure subtest of the DTVP-2. This finding suggests that one’s ability to recognize arbitrarily fragmented objects depends on one’s ability to recognize fragmented objects in general. Therefore, recognizing arbitrarily fragmented objects may represent a specific ability. However, the total of the four DTVP-2 subtests was related to identification for the RBC pictures. This finding suggests that the ability to recognize RBC pictures may depend on a number of related perceptual abilities rather than a single factor. For example, if an individual scores low on Visual Closure but high on Form Constancy, that person may still be able to recognize objects fragmented as long as sufficient information is present regarding the geons comprising the object. Further, these related perceptual abilities may compensate for each other.

According to the RBC theory, geons are fundamental for object recognition. The RBC pictures were recognized more often because the presence of geons contributed to better picture identification. Experience was more important for the arbitrarily fragmented pictures, whereas the RBC pictures were recognized across ages.

Although the research presented in this paper is consistent with RBC theory due to the regression analysis approach taken to determine factors influencing object recognition, replicating the current study with a larger sample size is warranted. In addition, once the validity of these findings has been verified, future research could examine the interaction of the perceptual skills used in object recognition. In addition, future research could include the percentage of geons needed for identification and, whether at a certain point, adding more geons no longer makes a difference.

References


