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OBJECT-RECOGNITION TASKS: COMPARING PAPER VERSIONS TO COMPUTERIZED LABORATORY METHODS [1]

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Summary.—This study attempts to generalize Biederman's 1987 findings regarding Recognition by Components theory, which were obtained using a computer administered object-recognition task, to an analog or paper task that is consistent with typical assessment or testing procedures. Three versions of an object-recognition task were developed after the Structure of Intellect–Learning Abilities Test by Meeker, Meeker, and Roid. One version contained randomly fragmented objects, one contained objects with vertices present, and the third contained objects with midsegments. 30 participants were administered each of the three versions in a counterbalanced order. The results are consistent with those of Biederman. Objects with missing vertices were more difficult to recognize than objects with missing midsegments. There was no difference between randomly fragmented objects and those with vertices present. Implications for object-recognition research and test-item development are discussed. In particular, it is suggested that perceptual theories should be used in developing test items to gain greater control in creating items of appropriate difficulty and to increase the validity of the overall instrument.

Recognition by Components theory (Biederman, 1987) suggests that visual objects are composed of geons. Geons are conical components that are derived from contrasts of five nonaccidental properties of lines in a two-dimensional image, i.e., collinearity, curvilinearity, symmetry, parallel, cotermination. The ability to detect these properties normally does not vary even when the image is viewed from a different position or the quality of the images changes. Biederman's model includes 24 geons that effectively form a visual alphabet. The same geons when combined differently form different objects. A complex object is composed of simple geons and can be identified by the individual geons. In fact, Biederman (1985) found that objects can be easily identified, even when degraded, as long as the geon information is recoverable.

The key to recovering a geon is determining its edges (Biederman, 1987). Once the edges are determined the geon can be identified (or recovered) and combined with other geons to form the object. Edges are composed of both vertices and midsegments. Vertices are intersections. Midsegments are lines that connect the intersections. Of the two features, Bieder-

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man (1987) found that degraded objects with vertices were recognizable while degraded objects without vertices were more difficult to recognize. However, Biederman used a highly controlled experimental procedure in which an object was presented on a monitor for 100 msec. with 500 msec. pre- and postmasks.

The methodology of object recognition studies is important. For instance, Snodgrass and Corwin (1988) presented line drawings in an implicit memory task and found that none of the line drawings were identified more than 35% of the time. However, Koch, Abbey, and Schmidt (1995) used the same line drawings as Snodgrass and Corwin (1988) in a naming task and found the line drawings were recognized 51% of the time averaged across line drawings. Therefore, the method of identifying objects influences recognition rate. This study was conducted to determine if the method of presentation influences how objects are recognized. In addition, a number of testing instruments incorporate subtests with degraded objects (cf. Carroll, 1993). Therefore, it is important to ascertain whether or not the same object-recognition principles apply to both computer administered objects and analog or paper versions of the same objects (cf. Kennedy, 1974). Specifically, this study compares line drawings of objects that have been randomly fragmented to those degraded by removing either vertices or midsegments. Consistent with Recognition by Components theory, line drawings with vertices should be easier to recognize than line drawings without vertices.

METHOD

Participants

Thirty upper division psychology students participated. All participants had normal or corrected to normal visual acuity.

Materials

Three versions of an object-recognition task were constructed following the format of the closure subtest in the Structure of Intellect–Learning and Abilities Test (SOI–LA; Meeker, Meeker, & Roid, 1985). In this test, a test sheet with 16 fragmented line drawings is presented for a 3-min. period. Therefore, 16 line drawings were matched for similar features to those presented in the SOI–LA from Snodgrass and Corwin (1988). The line drawings from Snodgrass and Corwin (1988) were fragmented according to the algorithm described by Snodgrass, Smith, Feenan, and Corwin (1987) in which parts of a picture in a specific pixel region are deleted. This deletion process occurs without regard to the types of information being deleted. The sheet formed with these 16 line drawings comprised the Random Deletion condition (Fig. 1a). An additional two sets of 16 line drawings, matched for similar features to those used in the SOI–LA, were selected from the Snod-

FIG. 1. Sample line drawings from each of the three conditions. The frog (a) was in the Random Deletion condition, the bell (b) was in the Midsegment Present condition, and the shoe (c) was in the Vertices Present condition.

grass and Vanderwart (1980) picture set. The vertices were deleted in one set of line drawings leaving the midsegments present. This sheet of 16 fragmented line drawings was the Midsegments Present condition (Fig. 1b). The second set of line drawings had midsegments removed leaving the vertices intact. This was the Vertices Present condition (Fig. 1c). All 48 line drawings were matched for contour deletion.

Design

Participants were administered all three object-recognition tasks. Half of the participants received the Vertices Present condition first followed by the Random Deletion and Midsegment Present conditions. The other half of the participants received the Midsegment Present condition followed by the Random Deletion and Vertices Present conditions. Thus, incomplete counterbalancing was employed. The number of correctly identified objects was recorded for each condition.

Procedure

Participants were given 3 min. to identify correctly the 16 fragmented line drawings in each condition. It is important to remember that 3 min. to name 16 line drawings essentially represents free viewing of the line drawings. Participants can name the line drawings in any order and can go back to items they could not initially recognize. This procedure is in contrast to computerized object-recognition studies which use brief presentation times and masked trials. Object names were recorded by the participants.

RESULTS

The mean number of correctly identified objects was 12.1 ($SD = 2.0$) for the Random Deletion condition, 11.5 ($SD = 1.4$) for the Vertices Present condition, and 8.4 ($SD = 2.4$) for the Midsegment Present condition. A repeated-measures analysis of variance yielded significant differences between conditions ($F_{2,58} = 34.75$, $p < .001$; $\eta^2 = .55$). An analysis of pairwise comparisons showed that significantly fewer items were correctly identified in the Midseg-

ment Present condition than in both the Random Deletion and Vertices Present conditions but no difference was found between the Random Deletion and Vertices Present conditions. Therefore, the line drawings were more difficult to recognize when the vertices were removed but no differences were found when at least some of the vertices were present. The later finding is consistent with Koch and Abbey (1999) who also found no difference between fragmented line drawings with vertices present and line drawings that had been randomly fragmented.

Discussion

This study was conducted in an attempt to generalize Biederman's findings (1987), which were obtained using a computer administered object-recognition task, to a paper task that is consistent with typical assessment or testing procedures. The results are consistent with those of Biederman (1987). Objects with missing vertices were more difficult to recognize than objects with vertices present. Randomly fragmented objects, however, contained a combination of vertices and midsegments and were as recognizable as objects with intact vertices and missing midsegments.

There are several implications for this study. First, despite differences in control and methodology, laboratory findings regarding object recognition can generalize to methods that involve less experimental control. This finding allows the use of paper versions of object-recognition tasks in research requiring a large sample size, e.g., intelligence or individual difference research. A typical object-recognition experiment may have 50 to 100 or more trials and be conducted under special viewing conditions. Paper versions, on the other hand, may have 30 or fewer trials (or objects) and are done under normal viewing conditions. Thus, paper versions reduce the amount of experimental time and eliminate the need for laboratory testing conditions both of which are important considerations in large *n* research. Second, test developers could benefit from using a theory of object recognition, such as Recognition by Components theory, when constructing tests. Presently, subtests with fragmented objects are developed using a random deletion process and the judgment of the test developer (Carroll, 1993). Relatively little attention is paid to the type of information being deleted. However, careful attention to the type of information being deleted can help create appropriate low-end, e.g., objects with vertices, and high-end, e.g., objects with some missing vertices, items. Low-end items are relatively easy items used at the beginning of a subtest while high-end items are relatively difficult items used toward the end of a subtest to differentiate between high and moderate levels of ability on the subtest. Using the principles of Recognition by Components theory to create fragmented objects for closure tasks in an assessment measure is consistent with recent research on new measurement models

which combine cognitive science and psychometrics to examine the cognitive components underlying problem-solving behavior (Embretson, 1996a, 1996b). Embretson (1998) has suggested that using theories to help create better test items is appropriate. Similar to the current study, Embretson's work has shown that attributes of the tasks in cognitive assessment can be calibrated and used to predict the difficulty of the tasks (Embretson, 1998). For instance, she has found that more complex cognitive demands result in more cognitive components, longer response times, and more difficulty for subjects to solve the items. Thus, the use of cognitive and perceptual theories in developing test items can significantly influence the construction of those items. In addition, a more thorough understanding of the theoretical underpinnings associated with cognitive and perceptually related items can potentially increase the validity of the test being developed.

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