The Effect of Experience on Spatial Skill

by

Kimberly J. Baker

May 15, 1984

Dr. Darrell Butler

Past research on three-dimensional interpretations of depicted objects indicates large variances among subjects' judgments (Butler & Baker, 1983; Shepard, 1981; Perkins and Cooper, 1980). What accounts for the large variance among subjects? Shepard credits the variance to stimulus ambiguity; many different interpretations can be formulated from one drawing. Perkins and Cooper believe it is the result of sloppy geometrical computations. They believe that perception operates more or less qualitatively rather than quantitatively which results in judgment errors. These accounts may not provide the entire explanation. The present paper examines the viewpoint that differences among subjects' skills and experiences with spatial tasks also may influence interpretations of depicted objects.

There is abundant research arguing that individual differences in spatial skills contribute to variability in spatial judgments (Cooper, 1982; Kail, Carter, Pellegrino, 1979; Tapley and Bryden, 1977). This paper examines three variables that may be important when judging depicted objects: (1) life or school experiences in drawing, (2) sex, and (3) spatial ability.

Experience

Research suggests that specific types of experience contribute to superior performance on spatial tasks and tests (Blade and Watson, 1955; Stringer, 1975). Blade and Watson provide evidence that college courses in engineering produced a significant gain in visualization test scores. The improvement was about three times as great as that of courses for non-engineering students. They also reported that precollege experiences, e.g. high school courses, hobbies, and work experiences in mechanical drawing, were also a factor in superior test performance. Specifically, all students with high visualization test scores had mechanical drawing experience.

In an experiment with freshman architecture majors, Stringer (1975) found that specific training improved scores on spatial tests. The freshman had previous formal instruction and practice in technical drawing. In the experiment one group received specific drawing training while the second group completed a conventional architectural design project in which there was no drawing required. In different spatial tests only one significant difference occurred between the two groups. This difference occurred on the DAT-SR which contains items requiring training that the first group was given. As expected, the first group showed superior performance. In four other spatial tests (Card Rotation, Cube Comparison, Form Board, and Paper Folding) the groups showed no significant difference.

There are several hypotheses concerning which skills are affected by experience (Cooper, 1982; Swann and Miller, 1982). Swann and Miller have shown that individuals who form highly vivid and clear visual images are superior in remembering information about the physical appearance of objects. Experience may enable an individual to create more vivid images.

Cooper (1982) believes that the primary effect of experience is on individual processing strategies. An individual primarily uses either analytic processing (sequential processing of an object in subunits) or holistic processing (processing in a parallel fashion). If given a choice, an analytic processor will process objects analytically and a holistic processor will process objects holistically. However, either type can adopt the other strategy. Holistic processors were found to be more flexible in their ability to adopt either strategy.

<u>Sex</u>

The literature provides controversy on whether sex differences in spatial ability exist. Tapley and Bryden (1977) state that sex differences do exist in mental rotation of depicted objects. Males were faster and more accurate in making judgments. Stericker and LeVesconte (1982), however, disagree. They argue that there are sex differences due primarily to differences in training. They found males more accurate than females on the pretest. They then provided spatial training tasks to both sexes and retested the subjects. Both groups benefitted equally and the females showed no significant difference in posttest scores from male control subjects. They argued that males' pretest scores were higher because they had more revelant pre-test experience.

Other research supports Stericker and LeVesconte (1982). Kail et. al. (1979) state that although men were faster in reaction times, all other aspects of the data (e.g. accuracy) were similar. Also, 70% of the females were as fast as the males. Only the remaining 30% were slower. In other words, greater variability among females accounted for the slower mean female reaction times.

Petrusic, Varro, and Jamieson, (1978) suggest that sex differences may exist for some spatial skills, but not for others. Sex differences were found on both the Card Rotation Test and the Mental Rotation Task (a modification of the Shepard and Metzler, 1971) but not on the Minnesota Paper Form Board Test.

Spatial Ability

There are many types of spatial tests. The tests appear to be capturing two types of spatial ability, spatial relations and visualization. Pellegrino and Kail (1982) state that spatial relations pertain to speed and accuracy of spatial processing. Emphasis is on two-dimensional, not three-dimensional, forms. Stericker and LeVesconte (1982) add that spatial relations pertain to comprehending the arrangement of the stimulus. They argue that spatial visualization emphasizes detail and mental manipulation of an object or part of a configuration.

The Present Experiment

Each of the factors described above may be important in explaining perception of depicted objects. However, Shepard (1978) and Perkins and Cooper (1980) limited their subjects to ambiguous stimuli, concluding that stimulus ambiguity or sloppy geometry were responsible for differences among judgments. Other researchers have used very unambiguous stimuli. Their conclusions differ. Tapley and Bryden (1977), Stericker and LeVesconte (1982), Kail et. al. (1979), and Petrusic et. al. (1978) explain that judgments are influenced by sex differences. Cooper (1982), Blade and Watson (1955) and Stringer (1975) believe that spatial skills or training are significant determinants of judgments.

The present experiment includes both ambiguous and unambiguous stimuli in an attempt to address the contributions of stimulus ambiguity and individual differences to judgments of depicted objects. Pellegrino and Kail (1982) claim that the Minnesota Paper Form Board (MPFB) is the spatial visualization test that least emphasizes speed and instead stresses detail and skill in manipulating internal parts of a stimulus configuration. For this reason the present research will use the MPFB to measure judgments of unambiguous stimuli. Judgments of ambiguous stimuli will be obtained using a Method of Adjustment procedure of 3-D interpretations of angles in simple line drawings (Butler and Baker, 1983). Both kinds of judgments will be compared to each other and analyzed in terms of subjects' differences in drawing training and sex.

METHOD

Subjects

A total of 40 students were solicited from the Ball State University School of Architecture, the art school, the industrial arts curriculum, and the general campus population. Subjects were divided into three groups. The experienced group (E), consisted of fourteen students with at least two drafting or technical drawing courses from either college of high school. The "some experience" group (SE), consisted of fourteen subjects with one drafting or drawing course from either college or high school. The "nonexperienced" group (NE), consisted of twelve subjects who had no drafting or drawing courses in college or high school. All subjects were paid $3.35 for approximately one hour of participation in the experiment.

Stimuli

For the method of adjustment task fourteen different stimuli were used (see Figure 1). Each stimulus was three intersecting lines defined by two angles (15°-15°, 15°-45°, 15°-75°, 15°-105°, 15°-135°, 15°-165°, 45°-45°, 45°-75°, 45°-105°, 45°-135°, 75°-75°, 75°-105°, 75°-135°, 105°-105°). Figure 1 shows the 45°-45° stimulus with the angle to be judged indicated by a small dash bisecting the angle 27 mm. from the intersection. The stimuli were drawn in the upper left corner of a 23 cm black and white CRT connected to an Apple II plus computer. Lines in the stimulus were white, 27 mm. long and approximately 1 mm. wide.

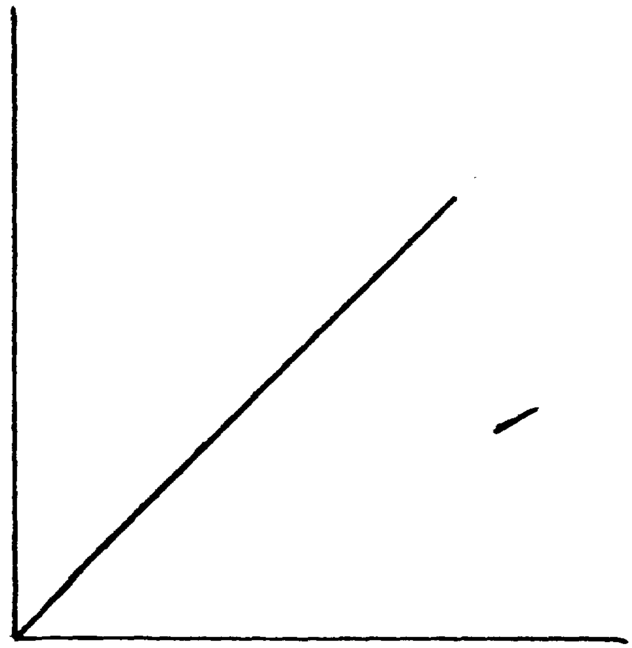

Figure 1. An intersection defined by two angles. The small dash indicates the angle to be judged.

Procedure

Each subject was run one at a time. First, the number of drafting or drawing classes of each subject was recorded. Then each subject was given instructions for the Method of Adjustment Procedure. The subjects were verbally instructed to adjust an angle in the lower right corner of the CRT to look the same as the indicated angle in the stimulus would look if judged from "straight-on." For example, the marked angle in Figure 1, if viewed as a corner of a regular box, would be a 90° angle if turned to face you straight-on. Half of the subjects were instructed to adjust the angle to the largest angle the stimulus could represent. The other half was told to adjust the smallest angle the stimulus could represent.

Subjects were then shown two demonstrations. Three wires in clay were used to demonstrate how angles in three-dimensional space appear different from different points of view. A three-dimensional block, triangle, and pyramid were also used to show the same phenomenon in objects.

The adjustment angle was defined by two lines (each line was 27 mms. long and approximately 1 mm. wide). Subjects used a dial and two buttons to make each judgment. The dial changed the angle between the two lines. The size of the angle depended on how much the dial was moved (bracketing was possible). To end a trial subjects pushed Button 1. This displayed two messages on the screen: (1) Push Button 1 to return to the stimulus, and (2) Push Button 2 to advance to the next trial. Subjects were required to wait at least a half second between pushing Button 1 and their second button press. This procedure prevented subjects from skipping angle judgments.

Subjects received 28 practice trials (each of the angles in the 14 stimuli). Responses were not recorded or analyzed. Subjects were not told that the first 28 judgments were practice trials.

Following the practice trials subjects viewed the same stimuli again. These responses were recorded. The order of the stimuli was randomized independently for each subject. A stopwatch was used to measure the total time subjects took in the task. Subjects were not told they were being timed.

After completing the Method of Adjustment Procedure the Revised Minnesota Paper Form Board Test, a 20 minute test that measures spatial ability, was administered. This test was handscored by two different people who compared scores and rechecked any discrepancies.

Results

Instructions did not have a strong effect on judgments. The data were first analyzed using angle size and instructions as independent variables in an ANOVA. Neither the main effect of instructions ($F\ (1,38) = 1.50$, N.S.) nor the interaction between instructions and angle size ($F\ (27, 1026) = 1.02$, N.S.) were significant. As expected, angle size was a very significant factor ($F\ (27, 1026) = 38.96$, $p < .0001$).

There are differences in judgments as a function of previous drawing experience. Figure 2 shows the mean judgments as a function of angle size and level of experience. The slopes of the best-fitting straight line of the three groups are significantly different ($F(2, 1116) = 3.55$, $p < .05$). As can be seen in Figure 2, the slope of the most experienced group is smallest, that is, the most horizontal.

The differences in judgment function slopes are probably not due to error rates. If random judgments are added to scores for an angle, the best-fitting line would be more horizontal but the standard deviations would increase. The mean standard deviation of angle judgments for the three groups are nearly identical [S(NE)=26.5, S (SE) = 27.2, S (E) = 28.2] although they do increase with decrease in slope.

The major reason for differences among experience groups appears to be differences in judgments that could be 90° corners (i.e. all 3 angles in apparent surfaces could be 90°). The five stimuli that could be 90° corners are: 15°-75°, 45°-45°, 45°-75°, 75°-75°, 105°-105°. A stepwise multiple regression analysis of the mean judgments of these ten angles for each subject was computed using sex, instructions, test score, and experience as predictors. Only experience was a significant predictor ($R(1,38) = .40$; $p < .01$). The mean judgments for each experience group show the progression toward 90° as experience increases [$\bar{X}$ (NE) = 79, $\bar{X}$ (SE) = 83, $\bar{X}$ (E) =88].

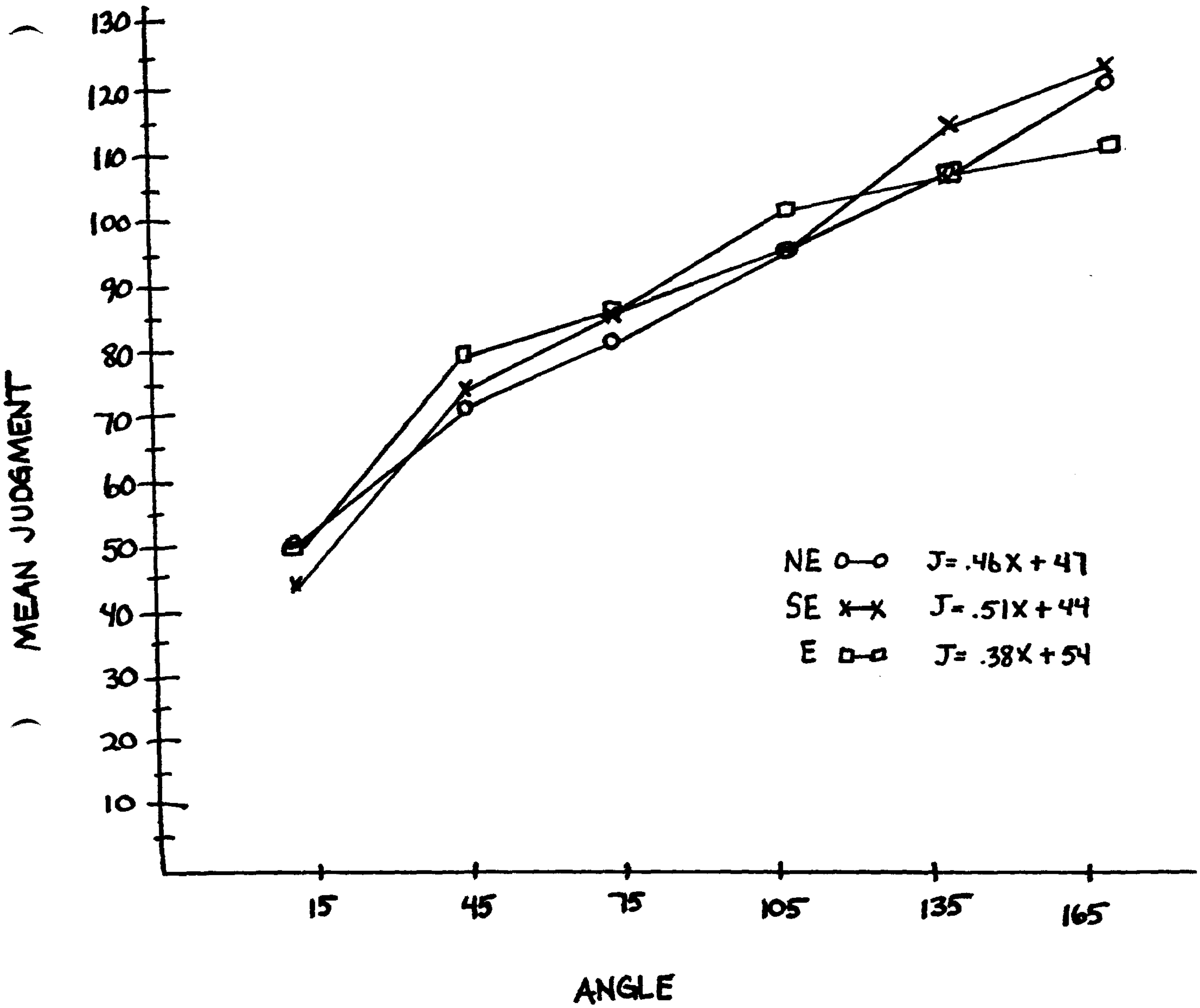

Figure 2. Mean judgments of raw data
for each angle across context.

Another variable that may be responsible for part of the difference among slopes is spatial ability. There is a high, significant correlation between spatial skill (as measured by the Form Board Test) and experience ($r\ (38) = .49$, $p < .002$). Both variables were also highly correlated to mean judgments of angles in 90° corners (r (exp) = .402 and r (score) = .396). The partial correlation between test score and mean judgment with experience accounted for was .25, which was not significant, but is noteworthy.

Sex cannot account for the obtained differences. It was not significantly correlated to experience ($r\ (38) = .26$, n.s.), spatial test score ($r\ (38) = -.08$, n.s.), or mean judgment of 90° corners ($r\ (38) = .25$, n.s.).

No differences in adjustment time were found as a function of mean judgment of 90° corners ($r\ (38) = .11$, n.s.), experience (4 (38) = .26, n.s.), spatial test score ($r\ (38) = .26$, n.s.), or sex ($r\ (38) = .29$, n.s.).

DISCUSSION

The present study provides evidence that some of the differences in subjects' judgments of ambiguous stimuli are due to individual differences in skills, especially drawing. However, each experience group had large variability among subjects. Thus sloppy geometry or ambiguity of stimuli are clearly strong factors in judgments of these stimuli.

The results show that individuals with above average experience in drafting judge depicted objects differently than non-experienced individuals--the judgment functions were more horizontal for the experienced subjects. Butler and Baker (1983) found similar results in an experiment involving increases in stimulus context. Judgment functions became more horizontal as more lines describing an apparent box were added to simple intersections such as those used in the present experiment. This suggests that the experienced subjects are acting like there is more context. Perhaps they are using top-down processing more than inexperienced subjects. This top-down processing was apparently most significant for 90° corner judgments. This result is consistent with the widely held belief among perceptual psychologists that there is a bias to see 90° whenever such an interpretation is consistent with projective geometry (e.g., Shepard, 1981). Our results suggest that the bias is stronger for experienced subjects.

Two alternative explanations may account for the differences between experience groups: (1) spatial ability is an innate characteristic, and (2) spatial skill is learned through individual training and experience. In our experiment subjects were not trained, rather they were selected. It is possible that it was not drawing training that was significant. Individuals with above average spatial ability may choose to enter art or architecture schools. Thus these results do not really shed any light on the question of whether spatial ability is trained or innate.

REFERENCES

Blade, M. F. and Watson, W. S. (1955). Increase in spatial visualization test scores during engineering study. Psychological Monographs, 69 (12, Whole No. 397).

Butler, D. L. and Baker, K. J. (1983). Three dimensional interpretations of intersecting lines: a challenge to theories of visual perception. Paper presented at the meeting of The Mid-American Psychological Association.

Cooper, L. A. (1982). Strategies for visual comparison and representation: Individual differences. In R. Sternberg, ed., Advances In The Psychology of Human Intelligence. Hillsdale, N. J.: Lawrence Erlbaum Associates.

Kail R., Carter, P., and Pellegrino, J. (1979). The locus of sex differences in spatial ability. Perception and Psychophysics, 26, 182-186.

Minton, H. L. and Schneider, F. W. (1980). Differential Psychology. Monterey, Calif.: Wadworth, Inc.

Pellegrino, J. W. and Kail, R. K. (1982). Process of spatial aptitude. In R. Sternberg, ed., Advances In The Psychology of Human Intelligence. Hillsdale, N. J.: Lawrence Erlbaum Associates.

Perkins, D. N. and Cooper, R. (1980). How the eye makes up what the light leaves out. In M. Hagen (Ed.), The Perception of Pictures, Vol. II: Durer's Devices: Beyond The Projective Model, New York: Academic Press.

Petrusic, W. M., Jarro, L. and Jamieson, D. G. (1978). Mental rotation validation of two spatial ability tests. Psychological Research, 40, 139-148.

Shepard, R. N. (1981). Psychophysical complementarity. In M. Kubovy and J. R. Pomerantz, ed., Perceptual Organization. Hillsdale, N. J.: Lawrence Erlbaum Associates.

Shepard, R. N. and Metzler, J. (1971). Mental rotation of three dimensional objects. Science.171, 701-703.

Steircker, A. and LeVesconte, S. (1982). Effect of brief training on sex-related differences in visual-spatial skill. Journal of Personality and Social Psychology, 43, 1018-1029.

Stringer, P. (1975). Drawing training and spatial ability. Ergonomics, 18, 101-108.

Swann, W. B. and Miller, L. C. (1982). Why never forgetting a face matters: Visual imagery and social memory. Journal of Personality and Social Psychology, 43, 475-480.

Tapley, S. M. and Bryden, M. P. (1977). An investigation of sex differences in spatial ability: Mental rotation of three-dimensional objects. Canadian Journal of Psychology, 31, 122-130.