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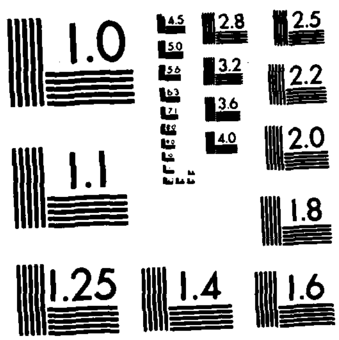

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Kosslyn, Brunn, Cave & Wallach (1982) tested 50 subjects on a battery of imagery tasks, and showed that the subjects differed in their ability to perform specific imagery operations (such as image scanning, rotation, and generation). In this study, the generality and reliability of the imagery analyses described in Kosslyn, et al. were examined by testing fourteen of the original subjects in a new imagery experiment. This experiment was conducted over one year after the initial task battery was administered, and relied on a task different from any of those used in the initial

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) battery. The task was designed to measure a number of components of the visual imagery process, and each subject's performance was predicted by his performance in the original tasks. In the 14 cases where correlations were expected between the old and new measures, only 2 correlations clearly failed to be obtained; and in the 12 cases where we did not expect to find correlations, only 2 were in fact found. The results supported the fundamental assumptions made earlier about image processing, and also hinted at some interesting strategic abilities and possible "set" effects in processing.

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ABILITY

IMAGERY AND TASK PERFORMANCE

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Abstract

Kosslyn, Brunn, Cave & Wallach (1982) tested ~~50~~ subjects on a battery of imagery tasks, and showed that the subjects differed in their ability to perform specific imagery operations (such as image scanning, rotation, and generation). ~~In~~ this study the generality and reliability of the imagery analyses ~~described in Kosslyn,~~ et al. were examined by testing fourteen of the original subjects in a new imagery experiment. This experiment was conducted over one year after the initial task battery was administered, and relied on a task different from any of those used in the initial battery. The task was designed to measure a number of components of the visual imagery process, and each subject's performance was predicted by his performance in the original tasks. In the 14 cases where correlations were expected between the old and new measures, only two correlations clearly failed to be obtained; and in the 12 cases where we did not expect to find correlations, only 2 were in fact found. The results supported the fundamental assumptions made earlier about image processing, and also hinted at some interesting strategic abilities and possible "set" effects in processing.

Imagery Ability and Task Performance

Kosslyn, Brunn, Cave, and Wallach (1982) asked whether people differ in terms of a general, undifferentiated imagery ability or in terms of a set of relatively independent abilities. They found that imagery is not a single ability but rather is based on a collection of distinct abilities. Further, the observed relations among task proficiencies corresponded well with the presumed similarity in underlying processing. The models of task processing were derived from the Kosslyn & Shwartz (see Kosslyn, 1980) general theory of imagery representation and processing. This theory posits a fixed set of structures and processes ("components") that are used to perform any given imagery task; tasks differ in terms of which components are used, and the more components two tasks share, the more similar the proficiency of performance was found to be. The components Kosslyn et al. examined included a "visual buffer" in which images occur (which has a limited extent, and a grain), a FIND process that classifies spatial patterns (images proper) as depicting specific objects, a REGENERATE process that holds an image in the buffer over time, a ROTATE process, and so on (see Kosslyn et al.). In this paper we examine the generality of individual differences in task performance, using completely different tasks on a subset of the subjects tested by Kosslyn et al. over a year after the original testing.

We set out to test the predictive value of our original measures by giving some of our earlier subjects new tasks, and comparing their performance to predictions derived from our old measures. We wanted a new task that would test as many components from the original tasks as possible, but one which would not require subjects to spend six hours in testing, as did the original battery. We devised a single task with three varying factors to assess different aspects of a subject's imagery ability, and supplemented it with a pencil-and-paper task to complete the assessment. We expected scores on the new tasks to be correlated only with the earlier scores in tasks putatively requiring the same underlying processing.

I. Dots Task

Subjects performing the dots experiment imaged a point moving through a field of randomly placed dots. Their objective was to determine whether or not the point would pass through any of the dots. To perform this task a subject must load an image into the image buffer, execute a translation transformation on the point, and examine the image. Three aspects of the task were manipulated: the size of the dots was varied to test visual acuity, the number of dots was varied to test the ability to maintain complex images, and the trajectory of the moving point was either straight or curved to measure the ability to perform regular guided transformations. By subtracting the time or errors made in one condition (e.g., many dots) from the other (few dots) we could control for all factors but those underlying the effects of the particular variation being examined (e.g., ability to hold large amounts of information in an image).

Materials

Fifty six slides were prepared, each displaying a different pattern of randomly placed dots. Each pattern contained from one to seven dots, and there were eight patterns with each quantity. In addition, half the patterns contained dots one-quarter inch across and half contained dots one-half inch across. Corresponding to each dot pattern slide were four other slides, each with a single small arrow (which was to be superimposed on the dot pattern). The position and orientation of the arrow varied from slide to slide. Half of the arrows were straight, and half were curved, with all the curved arrows being an arc of approximately 45 degrees from a 3 3/4" diameter circle. Half of each type of arrow were positioned so that a line extending from the arrow in the direction it was pointing (a straight line for the straight arrows, a curved line with the same amount of curvature for the curved arrows) would pass through the center of one of the dots, whereas the other half of each group were positioned so that such an extended line would not pass through a dot, but rather, through a point one-half inch away from the outer edge of a dot.

Two computer-controlled slide projectors, one for the set of random dot patterns and one for one of the four sets of corresponding arrows, were aimed at a rear projection screen so that their displays precisely overlapped. The subject sat in front of this screen with each hand resting on a telegraph key, the one under the dominant hand labeled YES and the other labeled NO. The subject sat with his or her head resting on a chinrest, with the dot display subtending 7.5 degrees of visual angle.

Procedure

A trial began when a subject was presented with one of the dot patterns. The subject was instructed to study the dots until he or she knew the pattern well enough to form an image of it, and then to press the

YES key. Then the dots disappeared, and two seconds later the corresponding arrow appeared. As quickly as they could, the subjects were to decide whether or not a point extended from the arrow would intersect any of the dots, and press the YES or NO key accordingly. The subject was to image the point flying along the trajectory specified by the arrow, moving as quickly as possible while going along a straight line or following the precise curvature of the arc of the arrow. The response and the time taken to make it were recorded. After one of the keys was pressed, the arrow disappeared, and five seconds later the next trial began. There were four blocks of trials, each having an equal number of displays in all possible conditions; each pattern of dots appeared once in each block, but paired with a different arrow. The order of the four blocks was counterbalanced over subjects.

Subjects

Of the 50 subjects who completed the original battery of individual differences tasks conducted in the first half of 1980 (see Kosslyn et al., 1982), 14 were available in the summer of 1981 to participate in this follow-up experiment. Ten were female, and five were male. They ranged in age from 20 to 49. Some had pursued education no further than high school, whereas others were enrolled in a graduate program (but not in psychology).

Results

We began by performing two analyses of variance, examining either the error rates or the reaction times (only times from correct decisions); these analyses considered the possible influence of number of dots, size of dots, curvature of arrows, and whether the extended line hit or missed a dot. As is evident in Table 1, both error rates and reaction times increased when more dots were included and when the arrows were curved: For number, $F(1,13)=6.67$, $p=.02$ for reactions times, and $F(1,13)=8.19$, $p=.01$ for errors; for curvature, $F(1,13)=19.81$, $p<.001$ for reaction times, and $F(1,13)=21.03$, $p<.001$ for errors. Unexpectedly, the size of the dots had no effect on either measure, $F<1$, for reaction times, $F(1,13)=1.31$, $p=.27$, for errors. Subjects made more false misses than false hits, $F(1,13)=4.77$, $p=.048$, and took longer to respond to trials which should have been hits, $F(1,13)=4.81$, $p=.047$. No interactions among times in the different conditions were significant, $p>.1$ in all cases. However, when straight arrows were used there were more errors when there were many dots, whereas the curved trials were already so difficult that the number of dots made no difference, $F(1,13)=5.46$, $p=.036$. Finally, when there were many large dots, subjects were more likely to evaluate a miss as being a hit, but the number of false misses was only slightly lower for a few small dots, $F(1,13)=4.97$, $p=.044$. Aside from these two interactions, the effects of each manipulation were independent, with all other interactions $p>.1$.

Insert Table 1 About Here

The analyses of primary interest all involved examining difference scores. The variations in conditions were intended to tax specific aspects of image processing, and we reasoned that the difference in performance between a high and low number of dots would reflect image maintenance ability, the difference between large and small dots would reflect image acuity, and the difference between a curved and straight arrow would reflect image transformation ability. And in fact, almost all subjects reported after the experiment that the trials with small dots, many dots, or curved arrows were more difficult, just as we expected. We therefore expected both the reaction times and the error rates to be higher for the more difficult trials on each dimension, and this was true in the curvature and number conditions as noted above. In contrast, neither dependent measure varied systematically with variations in size according to the analysis of variance. Apparently the differences between the sizes was not great enough to affect processing, and thus we ignored this manipulation in all subsequent analyses.

Thus, for each subject we obtained four measures, a difference between the two number conditions and a difference between the two arrow conditions for both times and errors. We then correlated these measures with the thirteen measures obtained using our initial task battery. Kosslyn et al. describe specific models of the processing being tapped by each of these measures. Given these models, which are summarized in Table 2, we expected correlations between our present measures and just those previous ones that shared the processing components assessed by the difference score. That is, the difference score was assumed to reflect the efficiency of the components taxed more heavily in one condition compared to the other. The more efficient the components, the smaller should be the difference score. For example, if one is able to hold many dots in an image at once, there will be a smaller difference in errors between the easy and hard number conditions than if one is not able to hold much information in an image at once. We correlated the _z_ scores assigned to each subject for each measure in our earlier test battery with the difference scores obtained here. The error difference score used here is simply the difference in error rates between the easy condition (straight line or few dots) and the difficult condition (curved line or many dots); the time difference score is the difference in times when the correct decision was made in the respective conditions. The results of this analysis are presented in Tables 3 and 4.

Insert Tables 2, 3 and 4 About Here

The first thing to notice about Table 3 is that the number difference scores here were significantly correlated with 5 of the 6 earlier measures (either errors or time) that reflected, in part, subjects' abilities to hold images in mind over a period of time; in addition, only one measure, the VVIQ test, that purportedly did not reflect this ability was correlated with the present measures. A closer look at Table 3 reveals an expected result: the differences in error rates were negatively correlated with the earlier measures. In the initial task battery, higher $\underline{z}$ scores reflect better performance. Here, the smaller difference scores reflect better performance. That is, presumably people generally found it easy to maintain a small number of dots, and differences in ability were revealed primarily in how easily larger numbers of dots could be held in mind.

In contrast, the results for the times were exactly backwards from what we expected: now larger differences were positively correlated with $\underline{z}$ scores. In other words, the better subjects took more time with the larger number of dots. This surprising finding may suggest that one reason the poor subjects are poorer is that they try to go to quickly, and respond before they are entirely prepared. These people were not simply "jumping the gun" in general, however: the correlation between each subjects' overall time and error rate was $r = -.02$. Thus, the most straightforward account of the disparity in signs is the possibility of component-specific speed/accuracy tradeoffs. In this case, a person's REGENERATE component was either fast and relatively inaccurate or slow and relatively accurate with large numbers of dots. It is important to note that this would not be a general tradeoff, but would be specific to a single component. This notion is intriguing because in would support the fundamental claims being made here, that image processing is accomplished using a set of relatively independent components, and that people differ in their abilities to use these components.

Table 4 presents the correlation with the arrow shape difference scores. In this case, the difference in difficulty between scanning straight and scanning an arc is assumed to be a consequence of the added difficulty of guiding the point along a regular curved trajectory in the latter condition. This operation requires a more precise connection between an image inspection process and a transformation. In the earlier tasks two kinds of inspection processes were purportedly used (the FIND and RESOLUTION processes, detecting patterns and acuity differences, respectively), and two major classes of transformation were used (involving manipulating an image or adding additional parts to it). In the present task, the difference between performance in the conditions is purportedly due to how well the FIND process directs a translation process (which moves the point each increment). A total of 8 of the thirteen original measures purportedly reflect some sort of inspection-guided image transformations, as indicated in Table 2. When examining Table 4, note first that only 1 of the 5 tasks purportedly not incorporating such abilities correlated with either of our difference scores (times or errors). Further, this measure -- from the extent task -- was the only positive correlation among the 6 significant correlations with error rate differences. Next, note that 5 of the remaining tasks were highly correlated and two more were marginally correlated with the new measures.

In fact, only 2 of the 13 measures clearly failed to be correlated or uncorrelated as expected. Note that there is no reason to expect higher correlations with the original tasks that involved movement transformations: the difference score techniques used here effectively isolates just those components responsible for differences between the two conditions, which involve guiding a transformation. As is also evident in Table 4, the times were positively correlated whereas the error rates were negatively correlated, again suggesting component-specific speed/accuracy tradeoffs. Unlike the number results, however, we now found a tendency for people who made few errors with straight arrows to make more errors with curved ones, and vice versa, with the correlation between the two conditions being $\underline{r} = -.48$, $p<.05$; the possible implications of this will be discussed shortly.

In summary, of the 14 cases where we expected correlations, only 2 clearly failed to be there; and of the 12 cases where we did not expect correlations, only 2 were observed.

Finally, we next obtained estimated factor scores for each subject from the factor analysis performed on the original measures (see Kosslyn, et al.), and correlated these scores with the difference scores obtained here. The results are displayed in Tables 5 and 6. (Not surprisingly, none of the size differences correlated with any of the factors.) The factors were previously interpreted as reflecting the image interpretation process used in guiding the addition of new parts to the image (Factor 1), the degree of image resolution (Factor 2), and the efficacy of the image maintenance process (Factor 3); the other factors were not easily interpreted. The correlations between the reaction time difference for number and Factor 3 was -.39, which is only marginally significant, whereas this difference was clearly correlated with Factor 2. The derived factors were, however, related as expected for the difference in curved vs. straight trajectories: this difference correlates negatively with Factor 1, which seems to imply that people who are good at using the interpretive process to add parts to an image can also use that interpretive process to guide the path of a moving point.

Insert Tables 5 and 6 About Here

Discussion

Considered in the most general terms, the results are clearly consistent with our expectations: when we expected correlations with our earlier measures, we usually got them; and when we did not expect correlations, we usually did not find them. There were some unexpected aspects of the results, however. We initially expected that everyone would do well in the "easy" conditions (small numbers of dots or straight arrow) whereas only some people would do well in the "difficult" conditions. In fact, people showed great variability in the easy conditions. This observation underscores a basic finding of Kosslyn et al.: average people are generally very poor at imagery operations. A striking example of this was the fact that Cooper's (1975) college population subjects rotated images about three times as fast, on average, as did our subjects, who were recruited via a newspaper advertisement. A second surprise was the tendency to find negative correlations with error rates while finding positive ones with times, suggesting a speed/accuracy tradeoff. This possibility was interesting because it seemed to be component-specific; people were not generally being fast and inaccurate -- if they had been, the times should generally have been inversely related to error-rates, which they were not. Such component-specific tradeoffs suggest a great deal of independence in the operation of the components and also suggest that people may have strategic control over the operation of specific processing components.

Perhaps the most striking unexpected trend in the results was the tendency for people who had high error rates for curved arrows to have low error rates with straight ones and vice versa. Although this correlation was not quite significant, it suggests that people adopt a specific strategy which is difficult to "break out of." And people able to do so prefer to guide the point along a non-linear trajectory. If in fact such strategies are difficult to change, and if people tend to adopt a strategy based on their own underlying competences, then there these results may have important implications for training air traffic controllers. It is unclear whether this "set" effect actually exists in general and if it can be eliminated by training, but these seem to be important issues for future research.

II. Shapes Task

The geometric shapes task was a pencil-and-paper test designed to measure a subject's ability to construct an image from verbal instructions. Our subjects completed the shapes test halfway through the dots experiment, between the second and third blocks of trials. The results in this task were expected to be correlated with scores on measures in the initial task battery that reflected image generation components.

Methods

On each trial, the subject formed an image of a configuration of simple geometric shapes from a verbal description. Questions about the spatial relationships among the components of the image tested his or her ability to construct and use the image.

Materials

The geometric shapes used in this experiment were a rectangle 1 1/2" x 3", a circle 2 1/2" in diameter, and a right triangle 2" x 4" x 4.5". We composed ten different scenes containing these items, with the three shapes touching but not overlapping, and wrote a description of each configuration. We also prepared two true and two false assertions about the spatial relationships between the shapes in that particular configuration. An example of one configuration can be seen in Figure 1, with its description and corresponding questions in Table 7.

Insert Figure 1 and Table 7 About Here

Procedure

The subjects were first given examples of the three shapes cut out of black cardboard. They were to handle and study them for as long as they liked, and then were instructed to pay close attention to the relationships between the sizes of the shapes. When a subject felt that he or she was very familiar with the shapes, the shapes were returned to the experimenter and the subject was given a booklet containing the ten descriptions, each on a separate page. Each description was immediately followed by another page containing the four corresponding true-false question about the configuration. At the very beginning of the booklet was a description and a page of four corresponding questions for a practice configuration. The subjects were not allowed to see the shapes after they had received the booklet, and they were instructed not to draw any pictures of the configurations so that they would have to rely on their ability to image the shapes in the described configuration to answer the questions. The subjects were allowed as much time as necessary to complete the questions.

Subjects

Of the 14 subjects who participated in the dots experiment, all completed the questions, although some reported that the task was very difficult. One subject's scores were excluded from the results because he made drawings of the configurations in the booklet, despite instructions to the contrary.

Results

Each subject received a score, which was the number of questions answered correctly. The maximum possible score was 40. The highest score among our subjects was 37, and the lowest was 20. We began by correlating these scores with the original measures, just as we did with the difference scores obtained in the dots experiment. These correlations are presented in Table 8. Because higher scores reflect better performance on both the shapes task and the earlier task battery measures we expected positive correlations between the shapes score and measures reflecting image generation ability. This was not found. In fact, the difficulty in answering questions about the shapes seemed to lie primarily in the difficulty in holding the image over time--as reflected by the correlations with the line drawing scores and form board test, both of which fell into a cluster reflecting image maintenance capacity in the Kosslyn et al. analyses. In addition, some difficulty may have been due to differences in image acuity; however, the correlations with the acuity and extent measures were only marginally significant.

We next correlated the shapes scores with the estimated factor scores from the factor analysis. The results are presented in Table 9.

The only significant correlation is between shapes scores and Factor 2, which is associated with the RESOLUTION component. This correlation is very high, and buttresses our inference that the acuity of a subject's image was one factor affecting performance on this task.

Insert Tables 8 and 9 About Here

Discussion

Our failure to find correlations with the Described Scenes measure was surprising, given that both tasks involved using descriptions to arrange image scenes. The earlier measure was based on how well subjects could arrange 4 objects in an image, and then scan between them. However, Kosslyn et al. discovered that a major constraint on the accuracy of the scores was the available extent of the image "space." Some people had only a few degrees of visual angle that were clear in a mental image. Thus, our earlier measure did not tap what we had intended. This was, however, not realized until after the present experiment was completed -- we did not want to risk demand characteristic effects by knowing in advance what were the previous results. Given the nature of the task, requiring subtle spatial judgments, it is interesting that the main constraints on performing this task were a subject's ability to hold information in the image over time on tasks when line drawings were stimuli (as was true in the line drawing and form board tasks used earlier) and image acuity.

General Discussion

Two conclusions can be drawn from these results: First, people do differ in terms of specific underlying imagery components; we did not find that subjects generally did poorly or well in all conditions. Second, the patterns of correlations provide good evidence that such individual differences persist for at least a year and generalize across very different tasks. In fact, our present measures were so different from the ones used in the task battery that it is impressive that we found any interpretable relations among scores from such a small number of subjects.

The present results, although encouraging, were by no means perfect. We found positive correlations with time where we did not expect them and we sometimes failed to find expected correlations. One reason offered above for the reverse correlations was possible "component-specific" speed/accuracy tradeoffs. In addition, the previous task battery did not assess performance on individual components, but only on tasks utilizing sets of at least three (and as many as 5) components. Thus, our failures may reflect the fact that some of the components interacted with or were overshaddowed by others in the previous tasks. In order to investigate the possibility of strategic control over the operation of specific components, and to test the existence and generalized effects of these components, we need a new set of tasks: Performance on these tasks must primarily reflect the efficacy of one and only one component, with differing tasks being designed to assess different processing components. We are now developing such a battery, and will describe its properties in a subsequent technical report.

References

Kosslyn, S. M. Image and Mind. Cambridge, MA: Harvard University Press, 1980.

Kosslyn, S. M., Brunn, J. L., Cave, K. R., and Wallach, R. W. Components of mental imagery representation. Johns Hopkins University manuscript and ONR Technical Report, 1982.

Table 1. Results for the different manipulations (error rates are in parentheses).

Straight	Curved
2.284	2.784
(.34)	(.48)
Few	**Many**
2.394	2.674
(.40)	(.43)
Large	**Small**
2.522	2.547
(.40)	(.42)
Hit	**Miss**
2.315	2.753
(.36)	(.47)

Table 2. Components in models for the tasks.

	Components in Kosslyn & Shwartz Models[a]	Factors in Commonsense Theory[b]
ACUITY	RS + l + r + pan	v + c
OBLIQUE	RS + r + rot + f	m + v + c
EXTENT	RS + l + r + trns	v + c
REORG PT	F + P + R	s + m + v
NONREORG PT	F + P + R	s + m + v
GEN SLOPE	F + P + PUT	s
REORG TIME	F + PARSE + R + P	s + v + c
DES SCENE	PUT + SCN + f + r + p	m + c
ROT SLOPE	F + ROT + l	s + c
LINE DR PT	F + R + SCN	s + m + c
LINE DR NO	R + put + f + p	m
FORM BOARD	R + F + TRNS + ROT + l	s + m + v + c
VVIQ	RS + P + put + r + f	v

Note a. Capitol letters in the Kosslyn & Shwartz models indicate that a component was weighted. The abbreviations used are as follows: rs: RESOLUTION; l: LOAD; r:REGENERATE: pan: PAN; rot: ROTATE; f: FIND; trns: TRANSLATE; p:PICTURE; put: PUT; parse: PARSE; scn:SCAN.

Note b. The abbreviations used are as follows: v:vividness; m: memory capacity; s: speed; c: control (of transformations).

Table 3 . Correlations between original measures and number differences. With significance levels.

	TIME	ERRORS
*ACUITY	0.4650 P=0.047	-0.4433 P=0.056
*OBLIQUE	0.2420 P=0.202	-0.4610 P=0.049
*EXTENT	0.0611 P=0.418	-0.1912 P=0.256
REORG PROBES	0.3695 P=0.097	0.1241 P=0.336
NON REORG PROBES	0.2408 P=0.204	0.2447 P=0.200
GENERATION SLOPE	0.1242 P=0.336	0.1436 P=0.312
REORGANIZATION TIME	0.1051 P=0.360	0.1760 P-0.274
DESCRIBED SCENES	-0.0220 P=0.470	-0.0520 P=0.430
ROTATION SLOPE	-0.0182 P=0.475	0.2428 P=0.202
*LINE DRAWING TIMES	0.5253 P=0.027	-0.0153 P=0.479
*LINE DRAWING SCORE	0.6370 P=0.007	-0.0821 P=0.390
*FORM BOARD	0.5525 P=0.020	-0.0363 P=0.451
VVIQ	0.1315 P=0.327	-0.4638 P=0.047

*Indicates tasks in which an image theoretically was maintained over time using the REGENERATE process.

Table 4. Correlations between original measures and curve differences. With significance levels.

	TIME	ERRORS
ACUITY	0.2085 P=0.237	-0.0900 P=0.380
*OBLIQUE	0.4391 P=0.058	-0.1508 P=0.303
EXTENT	-0.2240 P=0.221	0.7666 P=0.001
*REORG PROBES	0.3263 P=0.127	-0.4554 P=0.051
*NON REORG PROBES	0.5431 P=0.022	-0.5979 P=0.012
*GENERATION SLOPE	0.4869 P=0.039	-0.6203 P=0.009
*REORGANIZATION TIME	0.4214 P=0.067	-0.4965 P=0.035
*DESCRIBED SCENES	0.4229 P=0.066	0.2611 P=0.184
*ROTATION SLOPE	0.2000 P=0.246	-0.4833 P=0.040
LINE DRAWING TIMES	-0.2246 P=0.220	-0.2993 P=0.149
LINE DRAWING SCORE	0.0177 P=0.476	0.0331 P=0.455
*FORM BOARD	0.0896 P=0.380	0.2422 P=0.202
VVIQ	-0.1202 P=0.341	-0.0950 P=0.373

*Indicates that the task theoretically requires using the FIND process to guide a transformation.

Table 5. Correlations between factors and number differences. With significance levels.

	TIME	ERRORS
FACTOR 1	0.1842 P=0.264	0.2119 P=0.234
FACTOR 2	0.3948 P=0.081	0.6160 P=0.009
FACTOR 3	-0.1885 P=0.259	-0.3867 P=0.086
FACTOR 4	-0.0685 P=0.408	-0.0813 P=0.391
FACTOR 5	0.2339 P=0.210	0.2687 P=0.176

Table 6. Correlations between factors and curve differences. With significance levels.

	TIME	ERRORS
FACTOR 1	0.4530 P=0.052	-0.6542 P=0.006
FACTOR 2	0.1655 P=0.286	0.1689 P=0.282
FACTOR 3	0.3397 P=0.117	0.3555 P=0.106
FACTOR 4	-0.3819 P=0.089	0.7957 P=0.001
FACTOR 5	0.2960 P=0.152	-0.2166 P=0.228

Table 7. Example of questions asked about images of geometric forms.

1.	The top of the circle extends above the midpoint of the rectangle	T	F
2.	The rectangle extends below the triangle	T	F
3.	The rectangle extends below the circle	T	F
4.	The triangle extends beyond the right of the circle	T	F

Table 8. Correlations between original measures and shapes task. With significance levels.

	SHAPES
ACUITY	-0.4232 P=0.075
OBLIQUE	0.2890 P=0.169
EXTENT	0.4383 P=0.067
*REORG PROBES	0.2358 P=0.219
*NON REORG PROBES	0.3160 P=0.146
*GENERATION SLOPE	-0.0240 P=0.469
*REORGANIZATION TIME	0.0488 P=0.437
*DESCRIBED SCENES	-0.0332 P=0.457
ROTATION SLOPE	0.0284 P=0.463
*LINE DRAWING TIMES	0.3372 P=0.130
*LINE DRAWING SCORE	0.7824 P=0.001
FORM BOARD	0.8607 P=0.001
*VVIQ	-0.0134 P=0.483

*Indicates that the task theoretically involves image generation ability.

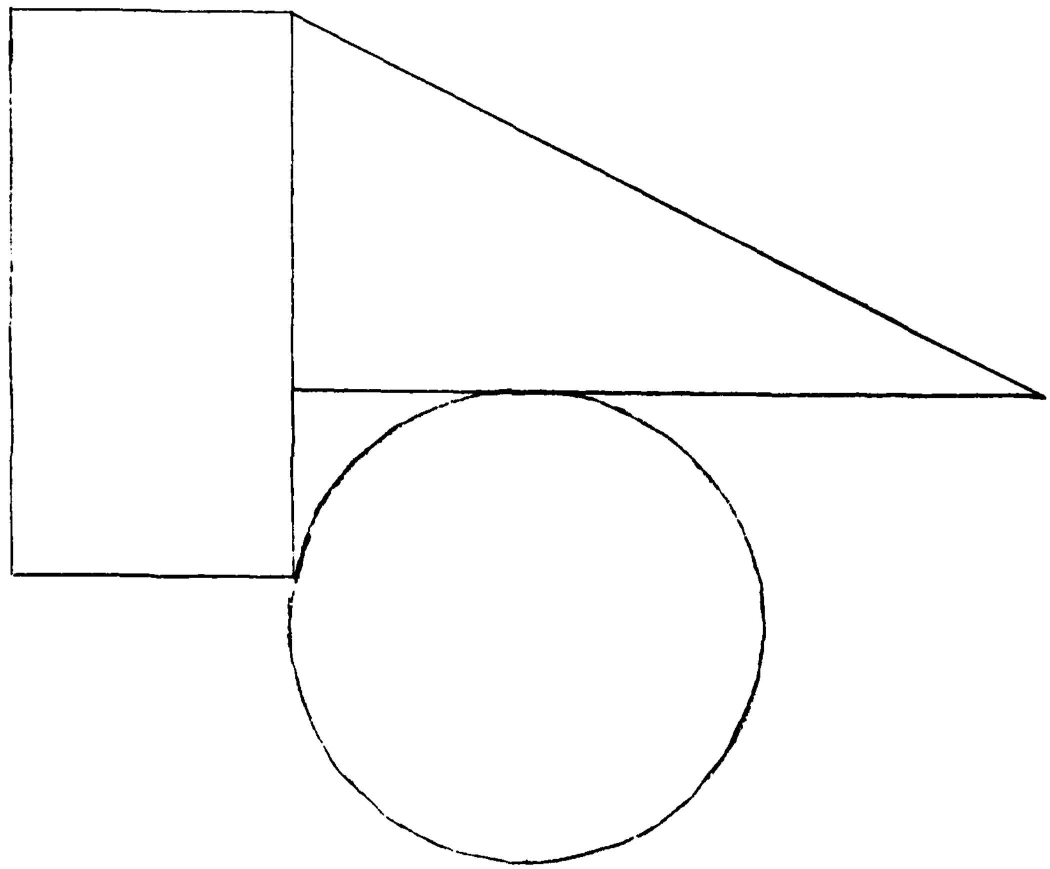
Table 9. Correlations between factors and shapes task.
With significance levels.

	SHAPES
FACTOR 1	0.1363 P=0.328
FACTOR 2	0.8728 P=0.001
FACTOR 3	-0.1037 P=0.368
FACTOR 4	0.2286 P=0.226
FACTOR 5	0.2123 P=0.243

Figure Captions

Figure 1. The configuration that should have been imaged when subjects read the following description:

> Place the rectange upright.
>
> Place the triangle on its side facing up, with the shortest side of the triangle against the right side of the rectangle, so that the uppermost point on the triangle is even with the top of the rectangle.
>
> Place the circle on the right side of the rectangle, under the triangle, so that it touches both of them.



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