The Effect of Spatial or Verbal Strategy Practice on Hand Involvement

Michela Anita LaRocca

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The Effect of Spatial or Verbal Strategy Practice on Hand Involvement

A Thesis
Presented to
The Faculty of the Department of Psychology
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

By
Michela Anita La Rocca
August 1989
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Elmer Faro  
Dean of the Graduate College
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The Effect of Spatial or Verbal Strategy Practice on Hand Involvement

Michela A. La Rocca
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Directed by: Sally Kuhlenschmidt, John Bruni, and Richard Miller

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A review of the research on spatial problem solving indicates that spatial problems can be solved using verbal or spatial strategies. Research on block designs further indicate that increased solving speed is correlated with increased left-hand use in right-handers. However, the effect of strategy teaching on hand involvement has not been explored. The present study selected 38 right-hand dominant college students low in spatial ability (Total Standard Score ≤ 95) using the Matrices Analogies Test (Naglieri, 1985). Subjects were randomly assigned to a spatial, verbal, or no (control) strategy condition. After completing the pretest consisting of seven block designs based on Grote and Salmon (1986), subjects spent 20 minutes on strategy training and practice on 67 two-dimensional spatial figures taken from the Dental Aptitude Test (Rudman, 1988). The same block designs used during the pretest were used in the posttest. Results indicate no significant differences in performance between the control and the treatment groups. However, within-group analyses suggest
that teaching either a spatial or verbal strategy may help subjects to improve in speed at least for the easier block designs.
INTRODUCTION

Research has demonstrated that subjects low in spatial ability can be taught strategies that improve their performance. One study (Grote, & Salmon, 1986) found that right handers preferred to use the left hand when solving complex spatial tasks (block designs). The purpose of the present project was to explore the impact of spatial or verbal strategy teaching on hand involvement. Based on prior research it was argued that teaching a spatial strategy should increase the use of the left hand while solving block designs, whereas teaching a verbal strategy should increase the use of the right hand while solving block designs.

Research on spatial cognition started in the early 1920's and primarily focused on psychometric properties (McGee, 1979). Factor analytic studies established that spatial aptitude was a mental process independent of verbal and analytical cognition. Studies found that spatial aptitude is made up of the following subcomponents: 1. spatial visualization, and 2. spatial orientation. Spatial visualization was defined as the ability to mentally rotate and manipulate a visually presented figure (McGee, 1979). Spatial orientation was described as the ability to redirect or reorient oneself with regard to external changes in the environment (McGee, 1979).

Spatial ability research in the 60's and 70's focused
on analyzing the occurrence of individual differences including consistent sex differences with regard to performance on spatial tasks (Snow, & Petersen, 1985). Studies with regard to sex differences found that females performed spatial tasks more poorly than males. Studies with regard to individual differences established that subjects differ with regard to strategy selection and with regard to the efficiency of application of these strategies. Snow and Petersen (1985) suggested that even though spatial problems can be solved by using verbal strategies or by using spatial strategies, there is a qualitative difference. Just and Carpenter (1985) reported evidence that verbal strategies prove inferior to spatial strategies especially in relation to complex spatial problems.

Evidence of hemispheric specialization with regard to spatial problem solving was provided by neurological lesion studies (McGee, 1979). Kimura (1967) found that patients who suffered right hemisphere brain lesions performed significantly lower on the Block Design subtest of the Wechsler Adult Intelligence Scale than patients with left hemisphere brain lesions. Studies done with subjects without brain damage provided evidence that spatial cognition is mainly processed by the right hemisphere (McGee, 1979).

To summarize, prior research established that solving spatial problems with spatial strategies was superior to solving spatial problems with verbal strategies. Subjects
with high spatial ability used spatial strategies while subjects with low spatial ability used verbal strategies when solving spatial problems. The purpose of the present research was to examine the hypothesis that subjects with low spatial ability perform poorly because they use verbal strategies. It was further hypothesized that these verbal strategies interfere with hand involvement. Consequently, left hand involvement should be increased by teaching subjects with low spatial ability spatial strategies to solve spatial problems.
REVIEW OF THE LITERATURE

Cognitive Research

According to McGee's literature review (1979), research on spatial ability started in the early 1920's and focused on factor analytic studies. Research established that the factor of spatial ability was different from the factor of verbal ability (McGee, 1979). Factor analytic studies provided strong evidence that spatial ability consisted of distinct subcomponents. The number of components within the spatial factor is currently being researched. For example, factor analytic research (Pellegrino, Mumaw, & Shute, 1985) distinguished three independent components within the spatial ability factor: 1. Spatial Orientation which involves the subject's re-orientation with regard to an externally changing stimulus, 2. Spatial Visualization which involves the ability to mentally rotate two or three dimensional visual stimuli, and 3. Spatial Relation which involves rapid judgement of whether a pair of stimuli are identical or different (Pellegrino et al., 1985). They also pointed out that the main difference between the spatial relation factor and the spatial visualization factor is the speed-power dimension. Spatial relation problems consist of relatively easy items in comparison to spatial visualization items. Due to lack of complexity, speed and accuracy become crucial factors to differentiate high spatial ability subjects from low spatial
ability subjects. Spatial visualization tasks consist of highly complex items, and high spatial ability subjects differ from low spatial ability subjects in the amount of solution errors they make (Pellegrino et al., 1985). Most research appears to combine the spatial relation factor with the spatial orientation factor, and therefore only distinguishes between a spatial orientation and a spatial visualization component.

Research further established the existence of between-group differences as well as within-group differences with regard to spatial problem solving (McGee, 1979). In their research on three dimensional mental rotation Just and Carpenter (1985) established that low spatial ability subjects rotated objects more slowly and less efficiently. They tended to lose mental track of variables involved in rotation. To correct for the inadequate rotation process subjects had to repeat it partially or completely. Just and Carpenter called this re-rotation process "subsequent rotation" (Just, & Carpenter, 1985). From their mental rotation research, Just and Carpenter further provided evidence that high spatial ability subjects differ in degree of rotation steps, and in the type of rotation coordinates during mental rotation (Just, & Carpenter, 1985). Analysis of individual differences in spatial visualization ability established that skilled subjects were more accurate in detecting small mismatches, and they were faster during the
process of stimulus encoding and stimulus comparison (Pellegrino et al., 1985). Pellegrino et al. (1985) further suggested that spatially skilled subjects process representations of stimulus objects analytically, whereas low ability subjects process holistically. Kyllonen et al. (1984) established within-group differences with regard to strategy selection. High ability subjects switched between several strategies, ranging from verbal-analytic to spatial. Low ability subjects were less flexible, mainly using verbal styles regardless of task complexity. Subjects high in spatial ability increased strategy switching as tasks increased in complexity. These findings raised the question of whether low ability subjects could improve their performance through strategy training.

Strategy Training

Experiments investigating effects of strategy teaching yielded mixed results (Blatter, 1983; Brinkman, 1966; Kyllonen, Lohman, & Snow, 1984). Kyllonen et al. (1984) proposed that most studies yielded mixed results because researchers neglected the fact that individuals not only differ in spatial aptitude but also with regard to their verbal skills. Kyllonen et al. (1984) found evidence that subjects who were high in verbal ability showed better improvement on spatial performance when being taught verbal-analytical strategies. Kyllonen et al. (1984) investigated whether specific strategy training could
improve the subject's performance on a related task. Their research indicated that strategy teaching and training not only improved the subject's performance but also improved performance on a transfer task. Strategy training appears to be influenced by the subject's general aptitude profile: performance improved for subjects with low aptitude profiles, but interfered with performance of subjects with high aptitude profiles (Kyllonen et al., 1984). Other studies confirmed the interaction effect between aptitude profile and strategy teaching (McGee, 1979; Snow, Lohman, 1984).

Research further established that strategy shifting becomes crucial in solving complex spatial tasks (Kyllonen, et al., 1984). In their attempt to analyze spatial visualization strategy processes of high versus low-ability subjects, Pellegrino et al. (1985) developed a variant of the Minnesota Paper Form Board test. Item variability ranged from easy items, which require a two step mental processing solution, to complex items, which require several steps of mental processing including mental rotation of elements. Results provided evidence that the two groups differed significantly in the form of encoding: high ability subjects encoded in an analytic and precise fashion, whereas low ability subjects encoded holistically. Further, low ability subjects failed to rotate elements in complex items suggesting their lack of strategy shifting.
Neurological Research

The concept of cognitive processing has been greatly influenced by neurological studies (McGee, 1979). Cognitive lateralization was primarily identified by research in brain pathology (Kolb, & Wishaw, 1985). These studies suggest that the right hemisphere is mainly specialized for spatial processing, and the left hemisphere is mainly specialized for linguistic processes. Anatomically, the left part of the body is controlled by the right hemisphere, and the right body is controlled by the left cerebral hemisphere (Searlman, Cunningham, & Goodwin, 1988).

Neurological research involving subjects with normal brain functions provided behavioral support for brain lateralization (McGee, 1979). Laterality was behaviorally manifested in numerous experiments. Hiscock and Kinsbourne (1985) showed that reading interfered with right but not left hand simultaneous finger tapping. O'Connor (1971) found that blind right handed subjects were better with the left hand when reading Braille. In studies involving left versus right ear advantage, Kimura (1961) used dichotic listening and found a right ear advantage for verbally translatable sounds, and a left ear advantage for melodies and other abstract sound patterns.

Hiscock and Kinsbourne (1985) pointed out that behavioral measures, even though they provide indirect evidence for brain laterality function, tend to be limited
in reliability, and validity especially when trying to establish cerebral asymmetry differences in the normal population with regard to issues such as learning disabilities etc. Also, studies investigating the relationship between handedness and spatial aptitude did not find significant differences between left and right handers (Sanders, Wilson, & Vandenberg, 1982). However, when investigating the performance of a homogeneous group of right handers on a block design task (Grote & Salmon, 1986), a shift from preferred right hand use to left hand use was observed to correlate with increasing design complexity. Further analysis found evidence that subjects who did not shift to left hand use were significantly slower in completing complex block designs, than subjects who shifted from predominantly right to predominantly left hand (Grote, & Salmon, 1986). Grote and Salmon concluded that hand involvement on the block design task was an indicator of hemisphere involvement. Increased use of the left hand they argued indicated increased right hemisphere involvement. The next step is to observe hand involvement with regard to teaching and practicing a spatial or a verbal strategy.

Hypotheses

Research has shown that subjects high in spatial aptitude tend to use spatial strategies (Pellegrino et al., 1985). Further, neurological studies have demonstrated the existence of hemispheric specialization with regard to
spatial and verbal cognitive processes (McGee, 1979). Grote and Salmon's results suggest that right hand dominant subjects switched to left hand use while solving complex block designs. However, the two factors have not been manipulated concurrently in order to determine the influence teaching and practicing a strategy has on a subject's performance and hand involvement.

The primary objective of this study was to determine the effects of verbal and spatial strategy teaching and practicing on hand involvement on a related spatial task. Strategy research has identified efficient strategies used by high spatial aptitude subjects. Grote and Salmon's results indicate a switch from predominantly right hand use to predominantly left hand use while solving complex block designs. The present study argued that practicing a spatial task with a spatial strategy should result in increased solving speed on a related task. Practicing a spatial task with a spatial strategy should also result in more use of the left hand on a related task. Furthermore, practicing a spatial task with a verbal strategy solution should result in decreased solving speed on a related task and increased use of the right hand. Finally, practicing spatial problem solving without strategy solutions should have minimal influence on the solving speed of a related task, and on hand involvement. In other words, the no-strategy control group should solve the related task faster than the
verbal group but not as fast as the spatial group. Furthermore, the no strategy control group should use the left hand more than the verbal group but not as much as the spatial group.
METHOD

Subjects

Subjects were selected from a pool of introductory psychology classes. Selection criteria were: a. right handedness, and b. a standard score of 95 or below on the Matrix Analogies Test (MAT). Of 70 subjects tested, 11 were unable to complete the experimental task. Experimenter error further resulted in excluding data from 9 subjects. Seven experimenter errors consisted of accepting incorrectly assembled designs as correct, and 2 experimenter errors consisted of poor quality videotapes which made interpretation of hand movements speculative at best. Thirteen subjects scored above the MAT cut off. Thirty-seven subjects who fit the criteria had a MAT mean standard score of 83.6 with standard deviation of 5.2. The minimum standard score was 74, the maximum standard score was 95. Thirty-eight percent (n= 14) were males, and 62% (n= 23) were females.

The thirteen subjects who scored above the MAT cut off score of 95 were used for post hoc comparisons. The group's mean MAT standard score was 107.2 with a standard deviation of 7.0. The minimum standard score was 98, the maximum 120. Thirty-one percent (n= 4) were males, and 69% (n= 9) were females. To yield greater power for comparisons with the low ability group, the high ability subjects were treated as one group. All subjects received extra course credit for
their participation. All subjects were naive with regard to the research hypotheses.

Research Assistants

One male and 2 female undergraduate research assistants served as experimenters. They participated in the research for course credit. The experimenters were naive as to the hypotheses of the present study.

Preselection Measure

The Matrix Analogies Test Expanded Form (MAT-EF) was used to preselect subjects with standard scores of 95 or below to screen for subjects who were below average with regard to spatial ability. The MAT-EF has been established to measure nonverbal ability (Naglieri, 1985). Four factors were established: Pattern Completion, Reasoning by Analogy, Serial Reasoning, and Spatial Visualization. The MAT-EF correlates highly with the Raven's Progressive Matrices (r = .71, <.01). Finally, Naglieri's research found no sex biases with regard to mean standard scores.

Dependent Variable Measure

Nine blocks from the Block Design subtest of the Wechsler Adult Intelligence Scale Revised (WAIS-R) were used for the transfer task. Eight block designs (Grote & Salmon, 1986), a sample design, and 7 designs varying from low, medium, to high spatial complexity served as stimuli. Design complexity was established integrating the following functions: a. calculating the number of possible patterns
which can be made from the set of alternative block sides (Garner, 1962): b. the number of alternatives obtained when the design is turned through successive 90 degree rotation; and c. counting the number of adjacent same-color edges (Royer & Weitzel, 1977). Each design was centered on a 3X5-inch white piece of cardboard with red ink representing the block surfaces. The subject's time for completion of each design was recorded, as well as the use of the left and right hand during completion of each design. Hand involvement was used as a multiple dependent variable to measure right, left, and both hand involvement, as well as design completion time.

**Practice Stimuli**

The Dental Aptitude Test' (Rudman, 1988) contains 67 two-dimensional figures which have to be matched by selecting one or two separated parts out of four or five choices (Letter for permission to use the two dimensional items is in Appendix A). Correct solution requires mental rotation of the figures. In the spatial condition subjects were instructed to examine the key figure and then the possible choices, rotate choices as needed, and compare them to the key figure. In the verbal condition subjects were taught to verbally label the key figure, verbally describe all the choices, and then compare them to the original. In the practice condition subjects were merely told to select the appropriate match. All subjects were told if their
choice was correct or not and were given 20 minutes of practice.

Equipment

A block cardboard dispenser (Grote and Salmon, 1986) was used to organize the blocks before presentation of each design. A color video camera was installed in an adjacent room in front of a one-way mirror. The purpose of the video camera was to tape the subjects' hand movements during the block design task. A timer which was projected onto the screen was used to time the completion of each block design.

Design

A one way factorial design was used with two treatment levels (spatial and verbal), and a control level (no strategy).

Procedure

Subjects were randomly assigned to one of three treatment conditions. Upon arrival, the subjects were greeted by the research assistant and led into a room. The room contained a table pushed against a wall with a one-way mirror. A cardboard dispenser was placed on the table so that the hand movements were not obstructed by the dispenser during video taping. The video camera was in an adjacent room set up for taping through a one way mirror. While the research assistant requested the subject's consent to participate in the experiment (Appendix B), the author
prepared the video camera for taping. Next the research assistant filled out a data sheet requesting information about the subject's handedness with regard to writing, eating with a fork, brushing teeth, and throwing a ball (Sander et al., 1982), age (Pellegrino et al., 1985), and a history of brain injuries (studies have shown that brain injuries lead to restructuring of brain lateralization [Hiscock & Kinsbourne, 1987; Searlman & Cunningham, 1988]). The information sheet is in Appendix C.

The research assistant then said the following, "We are interested in how people solve various puzzles. You will be asked to work at several different tasks until you are successful. Please do your best on each type of problem. Do you have any questions?"

Block Design Pretest Condition

The research assistant proceeded with the block design task (Grote, & Salmon, 1986) by taking the WAIS-R blocks out of the box and placing them in front of the subject. The instructions were adapted from the Wechsler Block Design Test (Wechsler, 1981). The research assistant took one block between his/her fingers held it up so the subject could see it and said, "See these blocks? They are all alike. On some sides they are all red; on some, all white; and on some, half red and half white." Then the research assistant turned the blocks to show the different sides. The research assistant then placed the sample design directly in front of
the cardboard dispenser pointed to it and said, "I am going to put these blocks together to make this design. Watch me." The research assistant arranged the 9 blocks slowly to match the sample design. Then he/she gave the subject about 5 seconds to look at the blocks before scrambling the design while saying, "Now make one just like this." If the subject could not do it the research assistant demonstrated the sample again until the subject was successful.

Before starting with the first design the research assistant instructed the subject to place all the blocks into the cardboard dispenser with the all-white side facing forward. This procedure was repeated by the subject after completing each design. When the subject was ready to start with the first design the research assistant got up from the chair, to stand behind the subject and instructed the subject to sit in front of the cardboard dispenser so that both hands were able to reach the blocks equally well. The designs were prearranged so that the subject was presented with the easiest design followed by the designs with medium difficulty and then by the designs with high difficulty. Placing the top design directly in front of the cardboard dispenser the research assistant said, "Now make one like this. Tell me when you have finished." The research assistant encouraged the subject if he/she became frustrated by saying, "You are doing fine," or, "Some of the designs are difficult and it takes some time to solve
them," or, "Go ahead it is all right to try again." If subjects said they were finished even though the design did not match the model the research assistant replied, "That is not quite right, your design has to match the design exactly. Try until you match the design." During the block design task a second research assistant or the author was in an adjacent room to tape the hand movements during the block design task. When all designs were completed the subject was instructed to return the blocks to the cardboard dispenser before proceeding to the training condition.

Spatial and Verbal Training Conditions

For the verbal and spatial training conditions the research assistant read, "Now we would like you to learn a strategy for solving certain puzzles. The strategy involves the following concepts." The research assistant placed the instruction sheet in front of the subject and read the instructions carefully, stopping whenever the subject was to complete the sample exercises (see Appendix D for spatial, Appendix E for verbal, and Appendix F for practice instructions). After completing the instruction exercises the research assistant placed the last sheet of instructions in front of the subject and read, "We will give you 20 minutes to practice the strategy on the two types of tasks. We are not interested in how quickly you solve the designs but how well you learn to follow the steps." Then the research assistant explained how the subject was to follow
the strategy for each item. All subjects were told immediately if their choice was correct or not. If incorrect, the subject had to repeat all the strategy steps until he/she arrived at the correct answer. The research assistant then handed the subject the DAT booklet with 67 items containing two variations of two-dimensional spatial visualization tasks (Rudman, 1988).

Practice Condition

In the practice condition the research assistant followed the same instruction procedures described above but adjusted verbal instructions to match the practice condition. For the introduction the research assistant read, "Now we would like you to try solving certain puzzles," and instead of strategy emphasis the research assistant read, "We will give you 20 minutes to practice problem solving on the two types of tasks. We are not interested in how quickly you solve the designs since this is a practice exercise."

Block Design Posttest Condition

After completion of the treatment condition the research assistant collected all the materials from the subject, and prepared himself/herself to re-administer the block design task following the same procedures as in the first administration but leaving out the introduction of the blocks and the demonstration of the sample design. Again, another research assistant or the author taped the hand movements during the block design task in the adjacent room.
Manipulation Check

After completion of the last design the research assistant sat next to the subject and asked him/her the following questions, 1) "What do you think was the purpose of this experiment?" and 2) "Tell me how you went about solving the items." Finally, the research assistant read:

Thank you for your participation. This study examined spatial problem solving and whether it helps people to improve performance if they are provided with a specific strategy technique. We divided students into three groups. One group was instructed to practice spatial problem solving with a spatial strategy, the second group was instructed to practice spatial problem solving with a verbal strategy, and the third group was instructed to practice spatial problem solving without being provided a strategy. We are especially interested to see how these different strategies influence spatial problem solving and affect hemisphere functioning. If you wish further information about this study, leave your name and telephone number and we will call you when we have finished. Collecting and analyzing the data will probably take a few months. Please do not discuss the procedures with anyone else as we are not yet finished collecting data.

Videotape Data Collection

Total time was measured in seconds using the camera built-in timer. Time of hand involvement was measured in seconds for the right-, left-, and no-hand use. Both hand use was determined mathematically by subtracting no-hand use from total length of time. The new total time was then subtracted from the sum of the right and left hand time. A set of criteria to score the hand involvement was set up a
priori by the author (Appendix G). One research assistant together with the author practiced the criteria on a sample video using stopwatches as timers. Prior to the actual video tape data collection, timing of hand movements was practiced on a sample video. The times taken by the research assistant correlated .99 with the times taken by the author. During practicing timing of hand movements the author and the research assistant deviated up to .69 seconds when timing the same movements. During actual timing the research assistant and the author varied between .2 to .5 seconds with a standard deviation of .14 to .35 respectively. The average completion time was 65.4 seconds, average right-hand involvement was 54.0 seconds, average left-hand involvement was 51.3 seconds, and average no-hand involvement was 2.2 seconds. Further, during timing of the taped hand movements the research assistant and the author regularly double checked the others' time to check whether the time deviations were within the above-stated acceptable range. Also, timings were repeated on a regular basis to check for within-person consistency. The acceptable range for within person timing was the same as for the between person deviation. Finally, regular breaks of 15 to 20 minutes were taken and scoring sessions did not exceed 6 hours a day.
RESULTS

Prior to statistical analyses, the data set was checked for outliers. Outliers were defined by Barent and Lewis (1979) as observations whose means deviated more than three standard deviation from the sample mean. Pretest data yielded three subjects whose mean completion time deviated more than 3 standard deviations from the total group mean completion time. These three means were then replaced with the next highest mean of the total sample group. The new mean deviated 2 standard deviations from the group mean.

Planned comparisons examined completion time, right, left, and both-hand use with regard to moderately complex and highly complex post block designs. With regard to the hypotheses it was argued that the spatial group should show faster completion times, less right hand use but more left hand use than the verbal group. Further, the practice group should show the next fastest completion time, as well as the next highest amount of left hand use. Finally it was hypothesized that the verbal group should show the slowest completion times, the most amount of right hand use, and the least amount of left hand use with regard to post block task performance. It was decided post hoc to break down analyses by design complexity (moderate and high).

Moderately Complex Post Block Designs

No significant between-group differences were found with regard to completion times \( t(34) = 1.21, p = .23 \) for
the spatial and verbal group, $[z(34) = 1.41, p = .16]$ for the spatial and practice group, and $[z(34) = .20, p = .83]$ for the verbal and practice group. No significant group differences were found with regard to right hand involvement $[z(34) = .87, p = .38]$ for the spatial and verbal groups, $[z(34) = 1.39, p = .17]$ for the spatial and practice groups, $[z(34) = .54, p = .59]$ for the practice and verbal groups. With regard to left hand use no significant differences were found in group contrasts $[z(34) = 1.82, p = .07]$ for the spatial and verbal groups, $[z(34) = 1.72, p = .08]$ for the spatial and practice groups, and $[z(34) = .23, p = .96]$ for the practice and verbal groups. With regard to both hands, the practice group used both hands more than the spatial group $[z(34) = 2.10, p < .04]$. Table 1 illustrates pretest and posttest means for moderately complex designs with regard to completion time, right, left, and both-hand involvement.

**Highly Complex Block Designs**

For the highly complex designs no significant differences were found with regard to completion time $[z(34) = 1.05, p = .31]$ for the spatial and verbal groups, $[z(34) = .95, p = .34]$ for the spatial and practice groups, and $[z(34) = .60, p = .90]$ for the practice and verbal groups. No significant differences were found with regard to right hand involvement $[z(34) = .15, p = .8]$ for the spatial and verbal groups, $[z(34) = .74, p = .46]$ for the spatial and
practice groups, and \( t(34) = .60, p = .54 \) for the practice and verbal groups. Further, no significant differences were found with regard to left-hand involvement \( t(34) = 2.18, p > .05 \) for the spatial and verbal groups, \( t(34) = .87, p = .38 \) for the spatial and practice groups, and \( t(34) = 1.36, p = .18 \) for the practice and verbal groups. No significant differences were found with regard to both hand use \( t(34) = 1.3, p = .19 \) for the spatial and verbal groups, \( t(34) = .76, p = .45 \) for the spatial and practice groups, and \( t(34) = .57, p = .57 \) for the verbal and practice groups. Table 2 presents the pretest and posttest means for highly complex designs with regard to completion time, right, left, and both hand involvement.

**Post Hoc Analyses**

Tukey tests were applied to all post hoc analyses at the Family Wise alpha of .05 (Keppel, 1982). The tests examined performance from pre- to posttest, as well as the amount of hand involvement for the moderately and highly complex block designs in pre- and posttest. Besides the low ability treatment groups a high ability treatment group (MAT > .95) was examined with regard to pre- and posttest performance, and with regard to left, right, and both-hand involvement. Finally, the low, and the high ability groups were compared with regard to performance and hand involvement.
<table>
<thead>
<tr>
<th>Groups</th>
<th>Pretest</th>
<th></th>
<th></th>
<th>Posttest</th>
<th></th>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>10.3</td>
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<td>12.0</td>
<td>16.7</td>
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<tr>
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<td>39.1</td>
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<td>23.1</td>
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<td>16.7</td>
</tr>
<tr>
<td>Practice</td>
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<td>29.8</td>
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<td>19.1</td>
<td>16.2</td>
<td>22.3</td>
<td>14.7</td>
</tr>
<tr>
<td>SD</td>
<td>23.8</td>
<td>16.1</td>
<td>19.1</td>
<td>16.2</td>
<td>22.3</td>
<td>14.7</td>
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</tbody>
</table>

¹Time in seconds
²Hand movements in seconds.
### Table 2

**Highly Complex Designs: Means and Standard Deviations**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Pretest</th>
<th></th>
<th></th>
<th>Posttest</th>
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<td>Both(^2)</td>
<td>Total(^1)</td>
<td>Left(^2)</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>Hand</td>
<td>Hand</td>
<td>Hands</td>
<td>Time</td>
<td>Hand</td>
</tr>
<tr>
<td>Spatial</td>
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<td>48.6</td>
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<td>39.7</td>
<td>62.3</td>
<td>30.8</td>
</tr>
<tr>
<td>(n=11)</td>
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<td></td>
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<tr>
<td>SD</td>
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<td>29.4</td>
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<td>19.5</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SD</td>
<td>24.2</td>
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<td>23.8</td>
<td>33.4</td>
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<td>15.9</td>
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<td>92.0</td>
<td>48.7</td>
<td>72.9</td>
<td>37.4</td>
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<td></td>
<td></td>
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<tr>
<td>SD</td>
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<td>52.5</td>
<td>36.6</td>
<td>70.1</td>
<td>40.3</td>
<td>23.3</td>
</tr>
</tbody>
</table>

\(^1\) Time in seconds.
\(^2\) Hand movements in seconds.
Moderately Complex Design Pre. and Posttest Performance

All 3 low ability groups as well as the high ability group were examined to see whether they performed faster from the pretest situation to the posttest situation. The verbal and spatial groups improved in speed [\(t(12) = 2.18, p < .05\)] for verbal, [\(t(10) = 2.84, p < .05\)] for the spatial group. The practice group did not solve the designs faster from pretest to posttest [\(t(12) = 1.95, p = .07\)]. The high ability group also solved the designs faster from pretest to posttest [\(t(12) = 4.30, p < .05\)].

Highly Complex Design Pre and Posttest Performance

Again all groups were examined to see whether they became faster solving highly complex designs from the pretest situation to the posttest situation. All three low ability groups solved the highly complex designs faster from pretest to posttest [\(t(12) = 4.66, p < .05\)] for the verbal group, [\(t(10) = 4.08, p < .05\)] for the spatial group and [\(t(12) = 3.90, p < .05\)] for the practice group. The high ability group also solved the highly complex designs more quickly from pretest to posttest [\(t(12) = 2.85, p < .05\)].

Hand Use for Moderately and Highly Complex Designs

Neither the low ability groups nor the high ability group used one hand more often over the other hand regardless of design difficulty or pre-, or posttest situation [\(F(1, 24) = .33, p = .56\)], and [\(F(1, 24) = .32\).
\[ r = .57 \] for left hand use during moderately and highly complex pretest; \[ F(1, 24) = 8.0, \ p > .05 \], and \[ F(1, 24) = 2.4, \ p = .13 \] for right hand use during moderately and highly complex pretest; \[ F(1, 24) = .73, \ p = .47 \], and \[ F(1, 24) = .83, \ p = .37 \] for left hand use during moderately and highly complex posttest; \[ F(1, 24) = 4.3, \ p > .05 \], and \[ F(1, 24) = 7.2, \ p > .05 \] for right hand use during moderately and highly complex posttest.

**Performance of Low vs High Ability Groups**

In general, the high ability group was faster in solving the designs than the low ability group in all situations \[ F(1, 24) = 5.07, \ p < .05 \] for moderately complex pretest designs, \[ F(1, 24) = 14.99, \ p < .05 \] for moderately complex posttest designs; \[ F(1, 24) = 16.88, \ p < .05 \] for highly complex pretest designs, and \[ F(1, 24) = 15.04, \ p < .05 \] for highly complex posttest designs. Also, the high ability group used both hands more frequently when solving highly complex designs during the posttests \[ F(1, 24) = 5.13, \ p < .05 \]. Table 3 illustrates means and standard deviations for high and low ability groups during moderately complex pre- and posttest, and Table 4 summarizes the means and standard deviations of high and low ability groups at using left-, right-, and both-hands during highly complex pre- and posttest.
Table 3

Moderately Complex Designs: Total Times and Percent Hand Involvement

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
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<th></th>
<th>Posttest</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Total¹</td>
<td>Time Left²</td>
<td>Right²</td>
<td>Both²</td>
<td>Total¹</td>
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</tr>
<tr>
<td>Ability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>32.6</td>
<td>60.7</td>
<td>88.4</td>
<td>51.2</td>
<td>26.8</td>
<td>68.0</td>
</tr>
<tr>
<td>SD</td>
<td>7.6</td>
<td>22.3</td>
<td>6.9</td>
<td>24.2</td>
<td>4.5</td>
<td>14.5</td>
</tr>
<tr>
<td>Low</td>
<td>58.8</td>
<td>54.7</td>
<td>80.1</td>
<td>38.9</td>
<td>44.5</td>
<td>59.6</td>
</tr>
<tr>
<td>SD</td>
<td>41.2</td>
<td>29.5</td>
<td>7.9</td>
<td>24.5</td>
<td>15.7</td>
<td>32.4</td>
</tr>
</tbody>
</table>

¹Time in seconds.
²Hand involvement.
Table 4

Highly Complex Designs: Total Times and Percent Hand Involvement

<table>
<thead>
<tr>
<th>Groups</th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time %</td>
<td>Left %</td>
</tr>
<tr>
<td>Ability</td>
<td></td>
<td></td>
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<tr>
<td>High (n=13)</td>
<td>49.9</td>
<td>60.6</td>
</tr>
<tr>
<td>SD</td>
<td>21.9</td>
<td>19.3</td>
</tr>
<tr>
<td>Low (n=13)</td>
<td>108</td>
<td>55.0</td>
</tr>
<tr>
<td>SD</td>
<td>46.5</td>
<td>28.9</td>
</tr>
</tbody>
</table>

1Time in seconds.
2Hand involvement.

DISCUSSION
The present research was designed to test three hypotheses: 1. Practice on a spatial task with a spatial strategy should result in more use of the left hand, as well as increased speed on the block design posttest; 2. Practice on a spatial task with a verbal strategy should result in more use of the right hand, as well as decreased speed on the block design posttest; 3. Practice on a spatial task with no strategy should result in less use of the left hand than the spatial strategy but more than the verbal strategy group with a corresponding alteration in speed to completion.

Planned comparisons revealed no group differences with regard to completion time, right and left hand involvement. There was a group difference with regard to both hand involvement: the practice group used both hands more often than the spatial group during moderately complex post block designs. The present study argued that the use of the left hand could be increased by having subjects with low spatial ability practice spatial problem solving with a spatial strategy. The present study further argued that the use of the left hand could also be decreased by having subjects with low spatial ability practice spatial problem solving with a verbal strategy. Further, if subjects were allowed to practice spatial problem solving without being provided with any strategy, it was argued that this group should show more left hand use than the verbal group but
less left hand use than the spatial group because some of the subjects would practice with a spatial strategy while some would practice spatial problem solving with a verbal strategy.

However, the hypotheses were not supported. Furthermore, Grote and Salmon's left hand shift was not found in the present study. Neither the low ability treatment groups nor the high ability treatment group used the left hand more over the right hand or vice versa in either pre, or posttest or between moderately complex block designs and highly complex block designs. Thus this study failed to replicate Grote and Salmon's results. The question why the present study did not support Grote and Salmon's findings and therefore its own extended hypotheses needs to be addressed.

Differences in results may have been due to the studies' different methodologies. Grote and Salmon measured hand involvement by having one experimenter time the left and the right hand of a subject during the actual experiment. The left hand was timed by a stopwatch in the experimenter's left hand while the right hand was timed by a stopwatch in the experimenter's right hand. The present research videotaped hand involvement and timed left and right hand movement separately, following strict guidelines. Videotaped observations could be replayed if mechanical or other problems occurred. Questions arise with
Grote and Salmon's procedure of simultaneous timing of left and right hand involvement. One question concerns the equality of reaction time of left, and right eye-hand coordination in right handed people. It appears that right handers react more quickly with the preferred hand than with the nonpreferred. A differential bias may also occur while collecting data from two independent observations (left hand involvement, and right hand involvement). Besides the possibility of biasing one observation over the other the question of concentration needs to be addressed. It may be more difficult to hold concentration during the timing of one observation.

Assuming that the methodology of the present study was not a problem, then how can the results be explained? With regard to hand involvement, results of the present study revealed that the practice control group used both hands more while solving moderately complex post block design. An explanation with regard to these findings cannot be given at this point since the practice group did not differ from the verbal group with regard to both hand use. With regard to hand involvement, the results of the present study showed that subjects in all treatment conditions used the right hand as often as the left hand when solving all block designs. Interestingly, subjects with high spatial ability tended to use both hands more often than subjects with low spatial ability. If it is assumed that hand
involvement can be inferred to reflect hemisphere involvement, then these results suggest that spatial problem solving involves both the left hemisphere and the right hemisphere. The fact that the present study suggests a different role of hemispheric brain involvement than Grote and Salmon’s research underscores Hiscock and Kinsbourne’s reports that behavioral observations are not reliable indicators of hemispheric brain involvement.

Within-group analyses suggest that the spatial and the verbal groups benefited from the treatment. Speed increased from pre to posttest on moderately as well as highly complex block designs. The practice group got faster only on the highly complex block designs. These results indicate that subjects with low spatial ability equally benefited from verbal or from spatial strategy practice. Why the practice control group only improved on the highly complex designs is open to speculation. There may have been an immediate transfer effect from practicing strategies to the post block test which the practice group lacked. Also, since the practice control group solved the highly complex designs faster in the posttest one can argue that subjects in the control group may not have been concentrating as well as the treatment groups while solving moderately complex designs in the posttest. It appears that practicing with a strategy may have kept subjects in the treatment groups focused on the task, whereas subjects in the control
practice group may not have stayed focused on the task because they did not have to follow strict strategy guidelines. This point of view may be supported by the fact that all subjects in the practice group reported that they often guessed the answer while practicing the DAT. Subjects in the spatial and verbal groups often reported that they found the strategy useful and that they used them to solve the spatial problem solving.

Comparisons between the low spatial ability groups and the high spatial ability group should be interpreted with caution since the high ability subjects were pooled into one group regardless of strategy training. Results show that the high ability group was significantly faster in all treatment situations. Subjects with high spatial ability also used both hands more often than subjects with low spatial ability while solving highly complex post block designs. Within group analyses further showed that high ability subjects did not prefer the left hand over the right hand when solving highly complex block designs in either the pre or the posttest.

The present study better fit Kyllonen et al.'s research on strategy use and strategy training (1984). Kyllonen et al. found that subjects shift between verbal and spatial strategies depending on the type of problem. There are, for example, verbal and spatial encoding strategies which differ in the amount of processing time but not in
coming up with the correct answer. High ability subjects appear to use a more spatial approach whereas low spatial ability subjects tend to encode stimuli verbally. As for rotating figures, spatial rotation was found to be superior to verbal matching (Pellegrino et al., 1985). Again these findings suggested that high spatial ability subjects tend to rotate the figures before comparing them to the original stimuli whereas low spatial ability subjects tend not to rotate the separated stimuli. Since both spatial and verbal groups improved in the present study, results suggest that low spatial ability subjects in the verbal group benefited from some aspect of the verbal strategy, and low spatial ability subjects in the spatial group benefited from some aspect of the spatial strategy.

Future Improvements

Future research in this area should attend to several areas: subject selection, validity of the practice measure, experimental set up of the dependent measure, and data collection of the dependent measure.

With regard to subject selection, the present study preselected students with regard to their spatial ability. However, no information was gathered with regard to their verbal ability. One can argue that even though both types of strategy training yielded better results than no strategy training, there can only be speculations about the influence of the subjects’ preexisting verbal ability on the spatial
block design task. Some subjects may have benefited from preexisting high verbal ability. Further, even though the majority of the subjects said that the strategies helped them, there is no way of verifying whether the strategies were followed.

With regard to practice task selection, items from the Dental Admissions Test (Rudman, 1988) were used. These two dimensional geometric figures appeared to have face validity but there was no data available on other types of validity and reliability. Therefore one can only be speculated that the items were indeed measuring spatial visualization.

The block designs task adapted from Grote and Salmon's research served as the dependent variable measure. The present study used the block design task twice, during the pretest, and again during the posttest. Therefore subjects were exposed to the same designs twice within a short period of time. Even though all subjects were exposed equally, it can be argued that memory from the pretest situation may have affected subjects differently during post block performance regardless of the treatment condition.

Finally, with regard to video tape data collection the present study used the author and a research assistant as data collectors. The author as well as the research assistant had been involved in the actual testing of the subjects. Even though the research assistant was naive with
regard to the hypotheses the author certainly was aware of the hypotheses. At this point in time it is impossible to assess the degree of bias of the data collected from the video tapes. It seems likely that the bias only had minimal effect on the results: First, the experimenter stood behind the subject during the block design tests and only glanced at the designs to ensure their correctness. During videotaping the author's prime interest was to insure that the subjects' hands could be clearly seen on the video screen. Second, data collection from the video tapes was undertaken two weeks after testing of the 70 subjects. Even if the research assistant or the author may have remembered the subjects and their conditions, the video screen provided only a view of their hands and the subjects' identity number. Third, if bias was present, the results of the study would be expected to confirm the hypotheses and they did not.

Finally, results with regard to the high spatial ability group should be interpreted with caution because subjects were pooled into one group regardless of their treatment situation. The reason for treating the different conditions as one condition was to achieve greater statistical power. The fact that subjects had been in different treatment conditions was not taken into account during statistical analyses.

Future Research
The present study investigated the impact of various strategies on the speed and hand involvement of low spatial ability subjects in solving a transfer spatial task. Results, however, indicate that the verbal as well as the spatial strategies helped low spatial ability students to improve on a related spatial task. Several options for improving performance of low spatial ability subjects may be available.

The present study looked at the transfer effect of strategy training and practice on a related spatial task. For future research a more direct approach may be tried. Instead of having subjects practice a strategy on one task and measure its effect on a related task it would be interesting to measure improvement on the same task.

The strategies used in the present study were either spatial or verbal. Results show that practicing either strategy improved speed at least for the moderately complex designs. Future researchers may try to combine the two strategies to form a hybrid strategy. Based on the literature, a logical combination would consist of teaching the subject how to encode a geometric figure verbally (verbal encoding) and teach mental rotation to combine separate figures before comparing it with the encoded geometric figure (spatial rotation). Prior literature (Kyllonen et al., 1984) found that verbal encoding was more often used by subjects with low spatial ability. Verbal
encoding is much easier than spatial encoding and there has been no evidence of qualitative inferiority of verbal encoding versus spatial encoding. Prior literature (Pellegrino et al., 1985) further found that low spatial ability subjects failed to rotate separated figures. A combination of the two strategies should therefore be maximally profitable for low spatial ability subjects.

Finally, subjects should be screened for their verbal as well as for their spatial ability. Knowing both types of ability the researcher should be better able to control for individual differences by selecting a low-low, or high-low ability subject sample for testing. Even though the hypotheses of this study were not confirmed the results suggest that subjects with low spatial ability can improve their performance. Future research should concentrate on strategy subcomponents and come up with the best combination of verbal, and spatial subcomponent for a task. Future research may turn away from the question of hemisphere involvement and try to integrate the subjects' verbal and spatial problem solving capacities with regard to spatial problem solving, especially with subjects low in spatial, and verbal abilities.
Note: 1 "c" LEARNING CORPORATION items were used with permission.
Appendix A

Letter of Permission for DAT Items
Michael P. Rudman  
National Learning Corporation  
212 Michael Drive  
Syosset, New York 11791  

Dear Mr. Rudman,  

I would like permission to use two spatial relation tests which are published in the 1988 Rudman’s Questions and Answers on the DAT Dental Admission Test as part of a research project I am currently designing. Specifically, I would like to use the two tests for two-dimensional spatial relations. Items 1 through 52 of the first test, and items 1 through 25 of the second test will be used as part of the treatment condition for that project. Subjects will use these items to practice one of two problem solving strategies (spatial or verbal). Subjects will be given immediate feedback with regard to their performance. The title of my project is: Effects of Verbal and Spatial Strategy Practicing on Right Hemisphere Involvement. I will be more than happy to provide you with a copy of the results of this experiment. The authors names, addresses and affiliations follow:  

Michela A. La Rocca  
Department of Psychology  
Western Kentucky University  
Bowling Green, KY 42101  
(502) 842-0120  

Sally L. Kuhlenschmidt, Ph.D.  
Assistant Professor  
Department of Psychology  
Western Kentucky University  
Bowling Green, Kt 42101  
(502) 745-4417  

Thank you for considering this request.  

Cordially,  

Sally L. Kuhlenschmidt, Ph.D.  
Thesis Advisor  
Michela A. La Rocca  

February 27, 1989  

Permission granted for one time use (not publication) provided you state “NATIONAL LEARNING CORPORATION used with permission.”  

John Ryan, Student  
Right, Right
Appendix B

Informed Consent

In this one-hour experiment you will take a series of tests. These tests serve to assess various cognitive functions. One task will be videotaped in such a way that your identity is not revealed. Your name will not be attached to any of the test materials. By signing below you consent to participate in this experiment.

Student ID

[Signature]

[Print Name]

[Date]
Appendix C

Information Sheet

Student ID

Birthday______________  Sex_______

Year in School__________  Major_____

With which hand do you hold the fork?_________

With which hand do you hold the toothbrush?_______

With which hand do you write?_________

With which hand do you throw the ball?_________

Have you ever been knocked unconscious?_________

If yes, describe__________________________________________
Appendix D

Instruction for Spatial Treatment

To solve these next problems you need to learn about examining a picture.

You visually concentrate first on the design A and make a precise mental image of it. Spend as much time as you need to make sure you have an exact image of the design in your mind. After example A do the same for example B.

Now you need to learn about turning the parts mentally.

Look at the upper left corner of example A. Examine the design carefully then shift your eyes to the upper right and lower left corner of example A. Turn the separate parts so that they match the design in the upper left corner. If you examine the figure to be matched carefully, it will be easier to turn the parts so they match the design. After example A, do the same for example B. This time the separate parts are given to you in one picture.
Now you are ready to learn all the steps involved in the strategy.

Items A and B are examples of the two types of tasks you will get to practice. For items represented by example A you pick one out of the four choices in order to match the whole figure. For items represented by example B you pick two out of the five choices to match the whole figure. Even though the examples may appear easy, be sure you follow each of the steps carefully.

**STRATEGY STEPS**

1. Examine the figure you have to match
2. Search for a possible match
3. Turn the separated parts
4. Compare your created design with the original design
5. If the designs are the same, mark your answer, if they are not the same, repeat the whole process starting with step 1.
Appendix E

Instructions for Verbal Treatment

To solve these next problems you need to learn about describing designs in your own words.

You concentrate first on design A and describe it in your own words. Spend as much time as you need to make sure your verbal description exactly fits the design. After example A do the same for example B.

You have to learn about labeling each part of the choices.

Look at the upper left corner of example A. Describe the design in your own words, then shift your eyes to the upper right and lower left corner of example A. Describe in you own words all the separate parts and see whether these parts match the design on the upper left corner. If you label the figure you have to match carefully, it will be easier to look for the parts to match the design. After example A, do the same for example B. This time the separate parts are given to you in one picture.
Now you are ready to learn all the steps involved in the strategy.

Items A and B are examples of the two types of tasks you will get to practice. For items represented by example A you pick one out of the four choices in order to match the whole figure. For items represented by example B you pick two out of the five choices to match the whole figure. Even though the examples may appear easy, be sure you follow each of the steps carefully.

**STRATEGY STEPS**

1. Verbally describe the figure you have to match
2. Search for a possible match
3. Verbally describe all the separate parts
4. Compare your labeled parts with the parts of the original
5. If the designs are the same, mark your answer, if they are not the same, repeat the whole process starting with step 1.
Appendix F

Instruction for Practice Treatment

Items A and B are examples of two types of tasks you will get to practice. For items represented by example A you pick one out of the four choices to match the whole figure. For items represented by example B you pick two out of the five choices to match the whole figure. Even though the examples may appear easy, be sure you go over the problems carefully.
Appendix G
Instruction for Videotape Data Collection

Timing of No-Hand Involvement

No-hand involvement occurs when the subject does not touch or move the blocks in any way. No-hand involvement also includes the time immediately after the design is presented. Start your timer as soon as the design is presented and stop the timer as soon as the subject moves one or both hands toward the block dispenser. Moving one or both hands towards the block dispenser is considered a block getting movement. If one hand or both move to straighten or manipulate the design or anything else but the block getting movement, then the timer stays on for no-hand involvement.

Timing of Right-Hand Involvement

Right-Hand involvement occurs when the subject touches or moves one or more blocks in any way. If the right hand is the hand that gets the blocks out of the dispenser in a sequential manner, leave the timer on because the block getting hand movements are included in the manipulation of the blocks. Carefully watch the right hand as it manipulates one or more blocks. Remember, any movement that puts the right hand in contact with a block be it by holding a block in the hand, by touching, pushing, turning etc. one or more blocks is timed. If the block is released by the right hand and immediately picked back up in such a manner that you cannot activate the timer fast enough, the hand movement is considered part of the block manipulation and therefore timed. On the other hand, if the right hand releases a block and moves without apparent purpose either through the air, or on the table close to the blocks this movement is not considered belonging to right hand block involvement, and is therefore not timed.

Timing of the Left-Hand Involvement

Follow the exact identical procedure for the left-hand involvement as for the right hand involvement.

Both Hand Involvement

Timing for both hands is figured mathematically:

(Right Hand + Left Hand) - (Total Time - No-Hand).
References
REFERENCES


Pellegrino, J. W., Mumaw, R. J., & Shute, V. J. (1985). Analyses of spatial aptitude an expertise. In S. E. Embertson (Ed), Test design and development in psychology and psychometrics (pp. 46-76). Academic Press, INC.


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