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Cognitive strategies in recognizing misoriented objects based upon hemispheric dominance

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COGNITIVE STRATEGIES IN RECOGNIZING MISORIENTED OBJECTS
BASED UPON HEMISPHERIC DOMINANCE

A Thesis
Presented to
The Faculty of the Department of Psychology
San Jose State University

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

by
Chris Hoffman
December, 1994

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COGNITIVE STRATEGIES IN RECOGNIZING MISORIENTED OBJECTS
BASED UPON HEMISPHERIC DOMINANCE

Chris Hoffman

San Jose State University

Running Head: COGNITIVE STRATEGIES AND HEMISPHERIC
DOMINANCE

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Abstract

This study compared subjects from right-handed families with subjects from nonright-handed families in their ability to solve a mental rotation task when instructed to use one of three different strategies or given no instruction. All subjects completed the Vandenberg Test of Mental Rotation as a pre-test. Upon completion, subjects from each group were randomly assigned to one of four groups (a) mental rotation, (b) perspective change, (c) orientation-free, or (d) control. Each group received strategy instructions corresponding to the group assignment. Upon assignment, the subjects completed the post-test Vandenberg. Subjects then reported on the strategies they actually used. No difference in performance across strategy was found; however, gender differences were noted. Mental rotation proved to be the natural strategy choice of control subjects and the strategy most widely used when subjects were unable or unwilling to utilize the strategy as instructed.

Cognitive Strategies in Recognizing Misoriented Objects
Based Upon Hemispheric Dominance

Cerebral organization and skill lateralization have been topics of extensive research. Broca and Wernicke were two of the pioneers in discovering the hemispheric location of language (Foss & Hakes, 1978).

In the early 1960's, Roger Sperry and his colleagues, Jerre Levy and Michael Gazzaniga, began to examine lateralization by way of commissurotomy or "split-brained" patients. This surgery was used typically to reduce severe seizure activity of epileptics who had not responded to drug therapy. The study of these patients has provided an opportunity to experimentally examine lateralization (Bogen, DeZure, Tenthouten, & Marsh, 1972; Corballis, 1983).

Within the lateralization framework, it is generally agreed that the right hemisphere is responsible for spatial organization/imagery (Corballis, 1983; Gur & Reivich, 1980; Johnson, 1990b; Levine, Banich, & Koch-Weser, 1984, 1988; Zenhausern, 1978), creativity (Levy, 1985; Torrance, Reynolds, Riegel, & Ball, 1977; Zalanowski, 1986), humor (Johnson, 1990a, 1990b; Torrance et al., 1977), emotion (Corballis, 1983; Levy, Heller, Banich, & Burton, 1983; Levy, 1985; Torrance et al., 1977), and holistic processing (Levy, 1985; Levy et al., 1983; Torrance et al., 1977). The left hemisphere is credited with analytical (Torrance

et al., 1977; Zalanowski, 1986; Zenhausern, 1978), verbal (Annett, 1983; Bogen, DeZure, Tenhouten & Marsh, 1972; Levine et al., 1984; Levy et al., 1983; Loring & Sheer, 1984; Torrance et al., 1977), logical (Levy, 1985; Torrance et al., 1977; Zalanowski, 1986), mathematical (Sdorow, 1990; Torrance, 1977; Zalanowski, 1986), and sequential processing (Corballis, 1983; Torrance et al., 1977; Zalanowski, 1986; Zenhausern, 1978).

For clarification, "lateralization" refers to the localization of a specific skill (e.g., speech) in a particular hemisphere. "Hemispheric dominance" refers to the general tendency to use one hemisphere more than the other. Most of the disagreements about hemispheric dominance are not about its existence, but rather its magnitude (Levy et al., 1983). Popular psychology has advanced such terms as "right-brained" and "left-brained" implying a dichotomous situation. Corballis (1983) warns not to get caught up in "dichotomania" which he defines as "...the tendency to overpolarize and overdramatize the functional differences between the two sides of the brain" (p. 65). Further, he points out, there is more overlap and cooperation between the two hemispheres than there are differences. Having prefaced with this important point, he acknowledges and explores the origin, transmission, and expression of lateralization. Marian Annett (1972, 1983) proposes that the lateralization of speech is the "seed" of

cerebral dominance. The lateralization of speech is documented by the location of Broca's area, the motor speech area. The area is *usually* located in the left cerebral hemisphere (Tortora, 1983). However, Annett punctuates the "usually" of the preceding sentence and suggests a genetic transmission of the lateralization of speech. Other theoretical indices of hemispheric dominance include subject handedness, hemispheric blood flow (Gur & Reivich, 1980), electroencephalogram (EEG) readings (Loring & Sheer, 1984), conjunctate lateral eye movement (Gur & Reivich, 1980), visual field dominance (Burton & Levy, 1991) and ocular dominance (Freedman & Rovegno, 1981).

Theories on the Origin of Hemispheric Dominance

Annett (1972, 1983) proposes a "right shift" factor which, when present, induces the cerebral representation of speech in the left hemisphere and generally results in right-handedness. Annett (1983) claims that this factor determines hemispheric speech localization and its *coincidence* is dextrality. This incidental occurrence of right-handedness is not always strong enough to offset the effects of environmental (e.g., modeling parents) and pathological (e.g., cerebral trauma) factors. These factors are thought to account for the lack of one-to-one correspondence between handedness and speech laterality. Corballis (1983) suggests that Annett should consider

renaming the theory "left shift" to reflect the emphasis on cerebral lateralization.

When both parents provide the factor ($rs++$), speech is lateralized in the left hemisphere. In the heterozygous situation ($rs+-$), speech is also lateralized in the left hemisphere. In the complete absence of the gene ($rs--$), there is no directing of lateralization so it occurs randomly. In general, any amount of the shift factor directs lateralization; in its absence, the "Asymmetry Lottery" (Corballis, 1983) takes over. Annett (1983) calculates the genotypic frequencies for a normal population as: $rs--$ 18.5%, $rs+-$ 49.1%, and $rs++$ 32.4%. If unaffected by environmental or pathological factors, approximately 9.25% ($18.5\%/2$) of a normal population would have speech lateralized in the right hemisphere.

Irrespective of the lateralization of speech, the left hemisphere of the brain is thought to process information in a sequential manner, while the right hemisphere processes in a holistic fashion (Torrance et al., 1977). Empirical evidence supports the hypothesis that both developmental dyslexia and stuttering result from problems of sequencing (Corballis, 1983). Corballis (1983) proposes that these disorders are tied to inappropriate right hemisphere strategies.

In pooling evidence from sodium amytal and ECT (electroconvulsive therapy) studies on a non-normal

(epileptics and clinically depressed) population, Corballis (1983) reports the lateralization of speech and its relationship to handedness. In the case of the right-handed subjects, 97% had speech lateralized in the left hemisphere and three percent had right hemispheric lateralization. For the left-handed or ambidextrous subjects, 68% had speech lateralized in the left hemisphere, 12% were bilaterally lateralized, and 19% were right hemisphere lateralized.

According to Annett's theory, a person with a *rs++* genotype has speech strongly lateralized in the left hemisphere and uses only his/her right hand. Since the parents must be either *rs+-* or *rs++*, his/her parents use only their right hands in major tasks. As a result of the strong lateralization of speech in the left-hemisphere, the *rs++* individual has a strong sense of left and right and can capitalize best upon sequential strategies in cognitive processing (Casey et al., 1986).

An individual with the *rs+-* genotype has speech lateralized in the left hemisphere and uses his/her right hand. According to the "right shift" theory, the individual with the *rs+-* genotype is less strongly lateralized to the left hemisphere. Pezaris and Casey (1991) call this genotype "ideal" because the *rs+-* individual can learn to utilize any cognitive strategy effectively.

In the case of the *rs--* individual, he/she could have speech lateralized in either hemisphere and as a result could display right-handedness, left-handedness or ambidexterity. The only way to be relatively certain that a person has a *rs--* genotype is if he/she is left-handed or ambidextrous. Corballis (1983) estimates that 89% of all left-handers are of the *rs--* genotype, while 11% are sinistral due to environmental or pathological influences. The *rs--* individual has difficulty in discriminating between left and right, but excels in using strategies such as spatial visualization that capitalize upon holistic processing (Casey et al., 1986).

For the purpose of categorization, Annett (1983) forces a dichotomous situation by dividing the three genotypes into two groups, "familial right" (*rs++*, *rs+-*) and "familial non-right" (*rs--*). Identification of the genotypes as proposed by Casey et al. (1986) is, at best, challenging and certainly not error-free. An individual expressing right-handedness could be any of the three genotypes (*rs++*, *rs+-*, *rs--*). Because of this, any individual who has nonright-handed (left or ambidextrous) family members, regardless of their own handedness, is classified in the "nonright" category. Casey et al. (1986) notes that

those individuals from families with nonright-handed members have the *rs--* genotype within their families.

Therefore, they would have a higher probability [italics added] of being an *rs--* genotype and a lower probability of being an *rs++* genotype than those individuals who come from families without any left handed or ambidextrous family members (p. 391).

While this heuristic could result in the misclassification of a *rs+-* individual as nonright, Casey et al. (1986) notes that "...the *rs+-* individual would be found among both types of families and would have no particular difficulty with either type of spatial strategy" (p. 391).

Individuals expressing left-handedness without familial history of left-handedness or ambidexterity are classified as "nonright." Though it is possible that this individual's handedness could be a result of trauma, it is also possible that he/she is a result of a heterozygous pairing (25% chance) whose speech is randomly lateralized to the right hemisphere. To be part of the "right" group, all immediate family members and the individual have to be right-handed (see Table 1 for an outline of Annett's classification with genotype shown in parentheses).

Annett (1972) suggests that some of the inconsistencies in the literature regarding handedness and its correspondence to cerebral lateralization are due to a failure to see handedness beyond the hand used to write. Consideration must be given to manual choices made for other tasks when determining handedness.

Table 1

Simple Mendelian Genetics as per the Right Shift Theory

Parental Pairings	Children
Geno / Annett	Geno / Annett
1) <i>rs++ x rs++</i>	
<i>(right x right)</i>	<i>rs++ (100%) (right)</i>
2) <i>rs-- x rs--</i>	
<i>(nonright x nonright)</i>	<i>rs-- (100%) (nonright)</i>
3) <i>rs++ x rs--</i>	
<i>(right x nonright)</i>	<i>rs+- (100%) (right)</i>
4) <i>rs+- x rs--</i>	
<i>(right x right)</i>	<i>rs+- (50%) (right)</i>
	<i>rs-- (50%) (nonright)</i>
5) <i>rs+- x rs+-</i>	
<i>(right x right)</i>	<i>rs++ (25%) (right)</i>
	<i>rs+- (50%) (right)</i>
	<i>rs-- (25%) (nonright)</i>
6) <i>rs++ x rs+-</i>	
<i>(right x right)</i>	<i>rs++ (50%) (right)</i>
	<i>rs+- (50%) (right)</i>

geno= genotype

right= Annett's categorization for *rs+-* & *rs++* genotypes

nonright=Annett's categorization for *rs--* genotype

Corballis (1983) discusses a "maturational gradient" theory whereby hemispheric development alternates. The theory states that in a great majority of people (those with speech lateralized in the left hemisphere), the left hemisphere takes the lead through the development of language in early childhood. The right hemisphere then has its turn to lead in middle through late childhood where facial recognition and mental rotation skills are developed. Environmental influences are thought to play a role in the emphasis of skills and thereby the strength of that hemisphere in which the emphasized skill is housed (lateralized) from late childhood through puberty.

This theory is supported by studies looking at subjects with left hemisphere damage. When left hemisphere damage occurs before the onset of speech (about two years of age), there is not a lasting effect upon language development. It is thought that the right hemisphere is able to compensate for this loss. When left hemisphere damage occurs between age two and puberty, speech is increasingly disrupted (the older the subject at the time of incident, the greater the disruption). After puberty, left hemisphere damage results in almost complete loss of language skills (Corballis, 1983).

It is possible to see the "right shift" theory imposed on top of the "maturational gradient" theory. Annett's

proposed genetic factors could direct which hemisphere would lead off the developmental process.

Kosslyn (1987) proposes a theory by which hemispheric dominance occurs called the "Four Macroproperties of the Brain." He calls the first macroproperty "processing subsystems." This concept addresses the tendency of the brain toward modularization to facilitate special functions. In being modularized, the subsystems are easy to alter. The second property is "exercise." Simply put, this property states that the brain, like the body, becomes stronger and faster with work. The neural pathways once formed become entrenched with frequent use and are taken with greater ease in the future. The third property is "transhemispheric degradation" which addresses the limited pool of activation. When one hemisphere receives a larger amount of activation, the other will conversely receive less and subsequently atrophy. This is the "use it or lose it" concept from physical training. Finally, the "central bilateral control" property is proposed, whereby a single locus of control initiates subsystems to carry out any and all tasks. Kosslyn (1987) suggests that catalytic seed subsystems, like speech, are innately lateralized. The seeds require servicing from other subsystems. Those service subsystems, in an effort to meet the needs of the seed subsystems, lateralize. Lateralization drives the system (brain) over time toward hemispheric dominance.

This process he refers to as the "snowball effect" (Kosslyn, 1987).

Again, Annett's theory works well with Kosslyn's. As with the maturational gradient theory, consider the genetic factor of speech lateralization as the first in a chain of subsequent reactions. Modularization refers to the initial lateralization of speech in one hemisphere or the other. Exercise addresses the premise that the hemisphere housing speech becomes the lead hemisphere and with it, its mode (sequential or holistic) of processing is established. Transhemispheric degradation also fits the "right shift" theory in that as one hemisphere and its mode of processing is exercised, the other mode of processing becomes less comfortable and reliable. The seed subsystem concept reminds us that hemispheric dominance (and thereby the mode of processing) is not autonomous, but is "fed" from other cerebral resources, very much the way the vascular system meets the needs of tissues and organs.

Gender and Lateralization

Overall, adult males tend to do better than adult females on standardized tests requiring visual-spatial manipulation (Allen, 1974; Allen & Hogeland, 1978; Vandenberg & Kuse, 1978). Several theories on why this occurs and what it might indicate have been forwarded. One such theory combines the maturational gradient hypothesis outlined above with socialization factors. For those with

speech lateralized in the left hemisphere, late childhood and early puberty is the time for development of the right hemisphere and its accompanying skills (e.g., visualization). It is at this time when females tend to spend more time indulging in more sequential (verbal) activities and less in holistic (spatial) activities, while males do the opposite (Corballis, 1983).

Some studies cite "verbal precocity and socialization" as factors causing the gender disparity (Allen, 1974; Allen & Hogeland, 1978). As a result of these differing social experiences at a time of critical development, females tend to develop problem-solving strategies that are more concrete. Allen (1974) examined this dilemma from a different perspective. She identified typically "male" (i.e., visual) and "female" (i.e., concrete) problem-solving strategies used in solving a visual-spatial instrument. Ninety percent of the time, subjects' gender correctly matched that of the strategy used. The women who were incorrectly identified (i.e., used "masculine" strategies) tended to have higher scores than their female counterparts.

Some researchers attribute the differences in scores of these timed tests as being speed differences between faster males and slower females. The timed atmosphere is thought to cause females greater anxiety and thereby poorer

performance (Freedman & Rovegno, 1981; Mumaw, Pellegrino, Kail, & Carter, 1984).

Another point which may be relevant to the gender and performance issue has to do with the greater expression of right-handedness in females (i.e., the female mean is further to the right than the male mean) and a proportionally higher expression of left-handedness by males (Corballis, 1983). If the maturational gradient theory is correct, it may help explain this difference if developmentally the female brain begins earlier. In so doing, the female brain may become "entrenched" through left hemispheric exercise. When the appointed time for right hemispheric development comes, males may have less experience using the left hemisphere and may be more open to and skillful in using right hemispheric strategies.

Interestingly, children born to a left-handed mother are more likely to express left-handedness than those born to a left-handed father (Corballis, 1983). This led Annett (1983) to postulate that the "right shift" factor is genetically "sex-modified," expressing itself more strongly in females than males.

Application of Dominance

It could be that the degree of dominance in a particular hemisphere would predispose an individual to develop cognitive strategies which capitalize upon the mode of processing of that hemisphere. Recognition of

misoriented objects is a task that lends itself well to the study of this hypothesis. Typically, subjects are first trained to a three-dimensional stimulus. They are then asked if test stimuli of varying orientations around the x, y, and z planes are "same" or "different" (Cooper & Podgorny, 1976). The recognition of misoriented objects is an ideal tool for studying cerebral dominance as it can be solved using different cognitive strategies (Casey et al., 1986; Just & Carpenter, 1985). Some of the most often reported strategies include mental rotation (holistic processing), perspective change (combined holistic/sequential processing), and orientation-free/verbal (sequential processing).

Mental Rotation

Mental rotation is a strategy first proposed by Shepard and Metzler (1971). The subject utilizing this strategy imagines the rotation of the training stimulus and then compares it to the test stimulus, determining whether the two stimuli are "same" or "different." The results from these studies examining two- and three-dimensional stimuli, show that response time (RT) increases linearly with the angle of departure of the test stimulus from the training stimulus. The model proposed to explain this occurrence is as follows: (a) encode identity and orientation, (b) rotate mental representation to the orientation of the training stimulus, (c) compare, and (d)

respond (Shepard & Cooper, 1986). As mental rotation implies a high degree of spatial organization and imagery, which is seeded within the right hemisphere, subjects with right hemispheric dominance should have an advantage in speed of processing.

Perspective Change

Perspective change is another strategy for recognition of misoriented three-dimensional stimuli. In employing this method, both the object and the observer are within the "coordinate system" (Just & Carpenter, 1985). The subject imagines standing or floating at some point on or near the stimulus using left, right, up, and down directions to describe the training and subsequently the test stimulus. Just and Carpenter (1985) documented this strategy when they looked at high and low spatial ability in subjects performing the Cube Comparison task and then reporting strategies employed. "The object's orientation in space is kept constant, but there is a change in the representation of the viewing point, and hence the represented view of the object" (Just & Carpenter, 1985, p. 159). This strategy is analogous to map reading whereby the subject must maintain a clear percept of self in relation to the environment. Just and Carpenter (1985) note that the perspective change strategy is used more with relatively large visual stimuli than with small, potentially hand-held stimuli (e.g., a house vs. a cube).

Like mental rotation, perspective change implies a high degree of visualization; as such, subjects with right hemispheric lateralization should have an advantage in speed of processing (Casey et al., 1986).

Orientation-free/Verbal

An orientation-free strategy is yet another cognitive option. The orientation-free strategy differs from perspective change in that only the object is in the frame of reference. Carpenter and Just (1985) report that some subjects in the Cube Comparison task used a sub-vocal description of the training stimulus which was retained in working memory and then compared like a check list with the test stimuli for "same" or "different" categorization. Based upon the theory of hemispheric dominance, subjects with left hemispheric dominance would have an advantage in speed of processing when using this strategy as they would be able to more effectively capitalize upon their verbal skills seeded there.

In this study, I will attempt to determine whether there is a relationship between hemispheric dominance as indicated by the lateralization of speech and the effectiveness of the cognitive style used to solve the Vandenberg Test of Mental Rotation. This study replicates some aspects of the Casey, Brabeck, and Ludlow (1986) research which used Annett's guidelines (1972) for looking at "right" and "nonright" familial handedness groups and

their efficacy in using mental rotation and perspective change strategies. To provide a sequential processing option, this study will also include an orientation-free, verbal strategy as an additional level of the cognitive strategy independent variable. I would expect that members of the "nonright" grouping to excel in the mental rotation and perspective change strategies, while individuals in the "right" group should excel in the orientation-free, verbal strategy.

Methods

Subjects

Eighty subjects (58 males, 22 female) were selected from a pool of U.S. Army ordnance officers attending the Ordnance Officer Basic Course at Aberdeen Proving Ground in Maryland. Each officer recently received his or her bachelor's degree. Forty (29 males, 11 females) were labeled "nonright" and 40 (29 males, 11 females) were labeled "right". Within each grouping (right, nonright), the subjects were further broken down evenly into four treatment categories. The ratio of males to females between each of these four treatment categories differed slightly due to the uneven number of female subjects available. However, within each condition, the gender ratio was identical for the right and nonright grouping.

Measures

The Edinburgh Handedness Inventory (Oldfield, 1971) was used to identify each subject's preferred hand for a variety of tasks to include writing, drawing, throwing, using scissors, striking a match (hand holding match), opening a lid (hand holding lid), using a toothbrush, using a knife (without a fork), using a spoon, and using a broom (upper hand) (see Appendix C). The subject used plus signs (+) to indicate level of hand preference (++ strong preference, + moderate preference, + in both columns for no preference) for doing the tasks listed above. A score was obtained by subtracting the number of plus signs in the left column from the number in the right, dividing by the total number of plus signs and multiplying that result by 100. Using the same classification system as Casey et al. (1986), a score above +40 was used to categorize right-handed subjects; a score from +40 to -40 identified ambidextrous subjects; and a score below -40 classified left-handed subjects. The second section of this indicator is called the Family Handedness Questionnaire (Casey et al., 1986). It was used to classify immediate family members (mother, father, and siblings from the same pairing producing the subject) in terms of their handedness. This was done by asking the subject to answer the same questions asked of them in the earlier section of the Edinburgh

questionnaire regarding their immediate family members' hand preference.

The Vandenberg Test of Mental Rotation was designed as a pencil and paper version of the Shepard and Metzler (1971) test (see Appendix D). The standard (training stimulus) is pictured on the left, with four choices offered; two of the four choices are correct (see Figure 1). Subjects were instructed to identify both correct choices. Subjects were advised that speed and accuracy were both equally important. They were further told that their score would reflect both correct and incorrect choices, therefore guessing was not advised. The test was divided into two parts with 10 items in each part. Subjects were given 5 min to complete the first section, then given 1 min to rest, and given another 5 min to finish the test. The scoring, as suggested by Vandenberg and Kuse (1978), was determined by the "all or nothing," correct pairs method. If a subject incorrectly identified one of the two objects in a given question, no credit for the item was given. A total of 20 points were possible.

A post-test questionnaire was designed to determine the degree to which the subject was able to use the strategy instructions given (see Appendix F). This questionnaire also provided an opportunity for the subject to report overall difficulty as well as which strategies were employed when not utilizing the strategy as directed.

Correct answers: The second and fourth

Fig. 1. A sample Vandenberg Mental Rotation Test item.

Design and Procedure

The procedure was to initially assess each subject's likely genotype using guidelines established by Casey et al. (1986) using the Edinburgh Handedness Inventory (Oldfield, 1971). This was done prior to inviting the individuals to participate in the study to obtain equal pairing for gender and handedness between the "right" and "nonright" groupings. Once the "right" and "nonright" division was made, each division was further broken into four conditions: mental rotation strategy, perspective change strategy, verbal strategy, and control. Subjects were randomly assigned to each of the four conditions. The experiment was administered at two settings for each treatment. A total of 16 administrations were given where a mixture of right and nonright classified subjects took the test.

The subjects were given the Vandenberg Test of Mental Rotation as a pre-test. Subjects were advised that in each situation, two of the choices were correct. After the pre-test, each subject received verbal instructions (see Appendix E) on a strategy to use in solving the Vandenberg Test of Mental Rotation based upon their condition assignment. The instructions were read twice to insure clarity. The mental rotation group was told to imagine the rotation of the standard when comparing it to the test. The perspective change instructions asked the subject to

imagine himself or herself standing or floating at one end of the standard and then comparing that to the test. The orientation-free, verbal strategy instruction told the subject to describe the standard verbally as if giving directions on how it was designed (i.e., up two blocks, right three, etc.). The control group was given no instruction. The test was then re-administered. Finally, the subjects were asked to complete a questionnaire of the strategies used. The entire session took approximately 45 min.

Results

Pre-test Analysis

A 2 (right, nonright) x 4 (mental rotation, perspective change, verbal, control) analysis of variance was performed on pre-test Vandenberg scores. No significant main effect for handedness was found $F(1,72) < 1$ ($M=11.92$ nonright, $M=12.95$ right). Also, there was no significant main effect for strategy $F(3,72) < 1$ ($M=13.1$ mental rotation, $M=11.95$ perspective change, $M=12.95$ verbal, $M=11.80$ control). There was no significant interaction of handedness and strategy $F(3,72) = 1.07$. The results indicate that randomization was effective.

Post-test Analysis

A 2 (right, nonright) x 4 (mental rotation, perspective change, verbal, control) analysis of variance was performed on post-test Vandenberg scores. No

significant main effect for handedness was found $F(1,72) < 1$ ($M=14.0$ nonright, $M=14.3$ right). Also, there was no significant main effect for strategy $F(3,72) < 1$ ($M=13.15$ mental rotation, $M=14.0$ perspective change, $M=14.7$ verbal, $M=14.75$ control). Finally, there was no significant interaction of handedness and strategy $F(3,72) = 2.10$. The results indicate that neither handedness nor strategy used had an effect on the ability to correctly choose misoriented three-dimensional objects as compared to a training stimulus.

Overall Analysis

In the overall comparisons between post-test scores and pre-test scores; post-test scores were significantly better than pre-test scores $t(158) = 2.04$, $p < .05$ ($M=12.45$ pre-test, $M=14.15$ post-test). This result supports the presence of a practice effect.

Gender Analysis

When pre-test male scores were compared to pre-test female scores, the results were highly significant in favor of the male scores $t(78) = 6.45$, $p < .01$ ($M=14.40$ male, $M=7.32$ female). Male scores were again significantly higher when comparing post-test male scores to post-test female scores $t(78) = 4.88$, $p < .01$ ($M=15.67$ male, $M=10.14$ female). Female post-test scores were significantly higher than female pre-test scores $t(42) = 2.26$, $p < .05$ ($M=10.14$ post, $M=7.32$ pre). Male post-test scores compared to pre-test scores were not

significantly different ($M=14.40$ pre, $M=15.67$ post) $t(114)=1.50$, $p=.14$. A comparison of pre-test vs. post-test adjusted scores (the number of correct divided by the number of attempts) was also undertaken using .05 as the level of significance. The pre-test difference between males (0.76) and females (0.46) was 0.30, exceeding the critical value of 0.2289. The post-test difference of 0.22 (males .80, females .58) exceeded the critical value of 0.2193. While not significant, the verbal, right strategy is the only pre- vs. post-test result in which females did better than males (see Tables 2 and 3 for Gender Means and n by Condition for pre-test and post-test).

Questionnaire Results

Subjects were asked to report the strategy they used when not able to employ the strategy as instructed (see Table 4). Both the right and nonright groups report reverting to mental rotation. In the control situation, all of the right group and a majority of the nonright group reported using mental rotation as their natural strategy. Subjects were also asked to rate the level of difficulty in using the strategy as directed. The continuous scale began with 1 at the least difficult level and 7 at the most difficult level. A score above 4 was interpreted to mean that the subject had difficulty using the strategy. The mental rotation group reported the least of difficulty in using the strategy as directed; followed by the verbal

Table 2

Gender Means and n by Condition: Pre-test

Handedness/Gender	Pre-test Scores			
	Condition			
	MR	PC	VB	CN
NonR/Male	<u>M</u> =15.9 (<u>n</u> =7)	<u>M</u> =15.2 (<u>n</u> =6)	<u>M</u> =11.4 (<u>n</u> =8)	<u>M</u> =13.8 (<u>n</u> =8)
NonR/Fem	<u>M</u> =9.7 (<u>n</u> =3)	<u>M</u> =8.0 (<u>n</u> =4)	<u>M</u> =3.5 (<u>n</u> =2)	<u>M</u> =3.0 (<u>n</u> =2)
R/Male	<u>M</u> =13.3 (<u>n</u> =7)	<u>M</u> =18.2 (<u>n</u> =6)	<u>M</u> =15.4 (<u>n</u> =8)	<u>M</u> =13.4 (<u>n</u> =8)
R/Fem	<u>M</u> =9.7 (<u>n</u> =3)	<u>M</u> =6.8 (<u>n</u> =4)	<u>M</u> =9.0 (<u>n</u> =2)	<u>M</u> =6.5 (<u>n</u> =2)

Note. Maximum score = 20

MR=Mental Rotation   PC=Perspective Change

VB=Verbal   CN=Control

Table 3

Gender Means and n by Condition: Post-test

Handedness/Gender	Post-Test Scores			
	Condition			
	MR	PC	VB	CN
NonR/Male	<u>M</u> =16.0 (<u>n</u> =7)	<u>M</u> =16.8 (<u>n</u> =6)	<u>M</u> =14.3 (<u>n</u> =8)	<u>M</u> =15.5 (<u>n</u> =8)
NonR/Fem	<u>M</u> =11.3 (<u>n</u> =3)	<u>M</u> =12.5 (<u>n</u> =4)	<u>M</u> =7.5 (<u>n</u> =2)	<u>M</u> =5.0 (<u>n</u> =2)
R/Male	<u>M</u> =11.9 (<u>n</u> =7)	<u>M</u> =18.5 (<u>n</u> =6)	<u>M</u> =10.25 (<u>n</u> =8)	<u>M</u> =17.0 (<u>n</u> =8)
R/Fem	<u>M</u> =11.3 (<u>n</u> =3)	<u>M</u> =8.0 (<u>n</u> =4)	<u>M</u> =11.5 (<u>n</u> =2)	<u>M</u> =12.5 (<u>n</u> =2)

Note. Maximum score = 20

MR=Mental Rotation PC=Perspective Change

VB=Verbal CN=Control

Table 4

Strategy Use When Not Employing Strategy Instruction

Mental Rotation	Right	Strategy	Nonright
	40%	Concrete/Verbal	50%
	20%	Process of Elim	10%
	10%	None given	10%
	30%	As directed only	30%
Perspective Change	Right	Strategy	Nonright
	80%	Mental Rotation	70%
	0%	Concrete	20%
	10%	Guess	0%
	10%	As directed only	10%
Verbal	Right	Strategy	Nonright
	60%	Mental Rotation	70%
	0%	Process of Elim	10%
	10%	Guess	0%
	10%	None given	20%
	20%	As directed only	0%

Cognitive Strategies

30

CONTROL	Right	Strategy	Nonright
	100%	Mental Rotation	60%
	0%	Perspective Change	10%
	0%	Process of Elim	10%
	0%	Guess	10%
	0%	None given	10%

group; with the perspective change group reporting the most difficulty. The subjects were also asked to estimate the percent of time they were able to use the strategy as instructed. Again the mental rotation group reported the greatest degree of compliance with all of the subjects reporting use of the strategy half or more of the time. Within the verbal group, most of the right group reported using the strategy half or more of the time, with fewer of the nonright subjects reporting the ability to do so. In the perspective change group, most of the right group reported use of the strategy more often than not, while only half of the nonright had the same experience (see Table 5).

Discussion

Several findings from this study, some expected, others not, make an interesting case for the original hypothesis that hemispheric dominance would predispose an individual to hone cognitive strategies that capitalize on the mode of processing of that hemisphere. For females, post-test scores were significantly better than pre-test scores. Unexpectedly, the data did not significantly support familial handedness as a factor in the ability to utilize any particular strategy.

Of further surprise, the gender issue proved to be highly significant in both pre-test vs. pre-test and post-

Table 5

Percent of Time Able to Use Strategy as Instructed

Mental Rotation	Right	% of time using	Nonright
	0%	0%	0%
	0%	25%	0%
	20%	50%	10%
	60%	75%	60%
	20%	100%	30%
Perspective Change	Right	% of time using	Nonright
	10%	0%	0%
	0%	25%	50%
	30%	50%	10%
	50%	75%	40%
	10%	100%	0%
Verbal	Right	% of time using	Nonright
	0%	0%	10%
	20%	25%	30%
	0%	50%	20%
	60%	75%	10%
	20%	100%	30%

test vs. post-test analyses. Adjusted scoring using the proportion (the number of correct divided by the number of attempts) was done to determine if females might have been more thorough, even if perhaps slower. As noted in the earlier section, the inverse was the case, where males were more accurate. The verbal, right group displayed a non-significant, but interesting trend. The female subjects in that group not only improved but out-scored their male counterparts. Further, these same males were the only group that failed to improve from pre- to post- test.

The questionnaire results were also enlightening with respect to mental rotation. Subjects reported mental rotation as the most common natural strategy and, as such, used it as a substitute when unwilling or unable to utilize the instructed strategy. The mental rotation group also reported the greatest degree of compliance in strategy usage. Some support for the original hypothesis was seen when, within the verbal group, the right subjects reported greater use of the strategy than did the nonright group. Each of these findings will be discussed in turn.

Overall Analysis

As overall post-test scores were significantly higher compared to pre-test scores, a practice effect is indicated. The control group illustrates pure practice effect as members of both right and nonright groups were given the opportunity to utilize the strategy of their

choice for pre-test and post-test. The mental rotation, perspective change and verbal groups used a combination of strategies (i.e., instructed and self-selected) which resulted in equivalent improvement as compared to the control. The mental rotation group, while not achieving significance, showed the pattern of what is predicted by the hypothesis. When the mental rotation, right group had to utilize a strategy against their natural inclination in the post-test, they did less well. While the mental rotation, non-right group showed improvement from pre-test to post-test administration, capitalizing on their "natural" ability. It is also true that the "trend" predicted and seen in the mental rotation group was not evident in the verbal and perspective change groups. I submit that, as the questionnaire suggests, some members of these groups may have experienced difficulty in using the strategy as instructed (right for perspective change and nonright for verbal) and quickly reverted back to their preferred strategy. Whereas members of the mental rotation group reported use of the instructed strategy more than the other condition groups, this condition was more "pure" in its measure of strategy usage.

Gender

The highly significant findings of males outscoring females in visual-spatial tasks is consistent with the literature. The male results could reflect a ceiling

effect as their mode was the maximum score of 20 on both pre- and post-tests. If the ceiling effect was a factor, there could have been greater disparity between the two genders. As discussed earlier, one theory on poorer performance by females focuses on anxiety (Freedman & Rovegno, 1981; Mumaw, Pellegrino, Kail, & Carter, 1984). On the questionnaire, several female subjects noted a test to be taken later that day affecting their ability to concentrate on the Vandenberg. It is also worth noting that females as a whole completed less of the instrument. It seems that the timed atmosphere of the instrument was not to their benefit. It is possible that stress causes reversion to the more trusted cognitive strategy, which for females who tend to be more strongly lateralized to the left hemisphere would be the slower, sequential process.

Of interest in looking at gender is the verbal, right condition. This was the only condition in which females outperformed males. Further, it was the only condition in which any gender, in this case males, failed to improve from the pre-test administration. It is possible that the maturational gradient discussed earlier is at work here (Corballis, 1983). If, as Corballis suggests, the left hemisphere leads off the developmental process and females get a "head-start" as demonstrated by advanced verbal skills, they may be more invested in this mode of processing throughout right hemispheric development. As a

result, while the visual-spatial skill base would develop, it would not be as trusted, much like people who break the hand with which they write (maturational shift from left hemisphere development to right hemisphere development) and then revert back to it (left hemisphere) after it has healed (right hemispheric development is complete).

Non-typical Female Sample. This understudied sample population offered a unique opportunity to look at the gender issue as it relates to cognitive strategy. Pezaris and Casey (1991) hypothesized that the females who were most likely to do well on a visual-spatial exercise were those who had "ideal" social and genetic factors as defined by having a math or science major in advanced education. While this experiment was not devised to examine individual differences such as gender, that was the most salient of all of these experimental findings. The females in this experiment were all in a typically male dominated career field (military) and had all come through a male dominated educational path (ROTC or the United States Military Academy at West Point). It is interesting that when accounting for both the social and genetic criteria, the females of this experiment performed significantly worse than the males with similar social and genetic factors. It could be that the strong social factors influencing females to emphasize verbal skills and sequential processes early

in life are not overcome by simply being a math or science major or working in those fields.

Questionnaire

Mental Rotation. Mental rotation was the most commonly reported natural strategy regardless of familial handedness by the control group. Further, the questionnaire completed by subjects given strategy instructions shows that mental rotation was a commonly utilized strategy regardless of handedness when unable or unwilling to use the instructions.

Strategy by Condition. Most of the perspective change group, regardless of handedness, reported reverting to the mental rotation strategy. Members of the nonright, verbal group reported becoming frustrated with the slower verbal strategy and subsequently reverted to the mental rotation strategy. In both of these cases, it is likely that the subjects acted as if they were members of the mental rotation group. As such, the measures for these two conditions (perspective change and verbal) are not reliable. For the verbal, right group, most of the subjects reported consistent use of the verbal strategy. Strategy usage for this group resulted in an increase, though not significant, from pre-test to post-test. This is the pattern that would be predicted from the hypothesis. It would have been rewarding if the non-right, verbal group would have continued verbal usage for a true comparison.

Methodological Issues

Edinburgh Handedness Inventory and Hemispheric Dominance. There are questions about the use of the Edinburgh Handedness Inventory in determining familial handedness. Upon first administration of the inventory, it was clear that its ability to classify individual handedness was in some cases questionable. Corballis (1983) documents some of the same concerns from other researchers who suggest that the test be shortened to five items rather than ten. He recommends that the first five items be retained (writing, drawing, throwing, scissors, and toothbrush).

Further, with regard to the family handedness section of the inventory, subjects are asked to identify the handedness of immediate family members. The instructions advise the subject to label these family members as right-handed, left-handed, or ambidextrous using the same criteria used "above" for their own handedness. The point is that a formula is necessary to classify each subject to a handedness category (number of plus signs in the right column subtracted by the number of plus signs in the left column, divided by the total number of plus signs and multiplied by 100). The subjects do not have access to this formula. Further, the definition of "ambidextrous" on the inventory is the ability "to use both hands with ease," which is, at best, tenuous. According to Annett, an

ambidextrous family member is *rs--*, and per Casey et al. (1986) the immediate relative of that person should be considered NONRIGHT. For this experiment, I disqualified anyone who would have been classified nonright by this process alone. The Edinburgh inventory does not pose questions regarding the subject's adoption or any cerebral trauma that would cause disqualification as "normal." The issue of half-siblings is also absent. While I believe in Annett's genetic hypothesis, I do not have confidence in Edinburgh's inventory as an indicator, nor for that matter, Casey's logic in the classification of right and nonright groups. Future research might use Annett's theory with information on speech lateralization obtained from an EEG.

The Vandenberg Test of Mental Rotation. With regard to the Vandenberg Test of Mental Rotation, there appear to be a few differences in the literature from one administration and scoring to the next. Vandenberg and Kuse (1978) suggest that subjects be given 3.5 min to complete each section and that scoring should be done in the "all or nothing," correct pairs procedure for a maximum score of 20 as described for this experiment. This scoring procedure eliminates the need to correct for guessing. The results reported by Casey et al. (1986) used 5 min to complete each section and scores were obtained by determining the total correct items. The maximum score achievable with this method is 40. Freedman and Rovegno (1981) used 5 min for

section time limits and the correct pairs scoring method. Pzaris and Casey (1991) used the equivalent of 5 min (30 sec/item) per section and the total correct scoring method. If comparisons from one experiment to another are to be made, some consistency in administration and scoring is necessary. I believe a ceiling effect may have resulted for males due to the excess of time made possible by the 5 min/section used in this experiment.

Suggestions For Future Work. I suggest that follow-up work be done with some important changes. A more reliable indicator of the lateralization of speech such as an EEG is merited. Once this information is obtained a similar experiment with three treatment groups would be more helpful. The elimination of the perspective change treatment is in order as one visual-spatial strategy treatment group is sufficient. As subjects reported difficulty using the perspective change strategy, it is the obvious choice for elimination. The mental rotation strategy is the most natural and familiar visual-spatial strategy, and as such, should remain. Homogeneous male and female treatment groups might also minimize some of the test anxiety expressed by females. Vandenberg administration should follow the Vandenberg and Kuse (1978) guidelines of 3.5 min per section and the correct pairs scoring method. After the administration of the pre-test, a question should be posed to determine the subject's

natural strategy. Further, a comparison of the lateralization of speech as determined by an EEG versus Annett's classification might prove interesting.

If, as Annett proposes, the *rs--* individuals can have speech lateralized in either hemisphere, it seems reasonable that an *rs--* individual with speech in the left-hemisphere would have equal abilities in the use of cognitive strategies that capitalize on that hemisphere and reciprocally have weaknesses in strategies that utilize opposing modes of processing. As such, a duplication of the experiment using exclusively *rs--* subjects as determined by a non-intrusive method is in order to determine if there are differences. Those subjects could then undergo an EEG to determine the hemisphere of speech lateralization and see if *rs--* subjects with speech in the left hemisphere differ from *rs+-* and *rs++*.

In all, the results of this experiment are inconclusive as they relate to the hypothesis originally forwarded regarding cerebral lateralization. While proving this point was hampered by the experimental design factors listed above, gender as an individual difference came forward very clearly. In this experiment males recognized three-dimensional objects better and faster than females. This issue needs further research as to the mechanism for this performance difference. It would serve everyone well to be reminded that while this skill seems to favor the

male of the species, there are also skills for which the female is gifted.

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Appendix A: Signed Approval Forms

Office of the Academic Vice President • Associate Academic Vice President • Graduate Studies and Research
One Washington Square • San Jose, California 95192-0025 • 408/924-2480

To: Chris Hoffman
187 Monterey Rd.
Fort Ord, CA 93941

From: Serena W. Stanford *Serena W. Stanford*
AAVP, Graduate Studies and Research

Date: July 19, 1993

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Cognitive Strategies in Recognizing Misoriented
Objects Based upon Hemispheric Dominance"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Dr. Serena Stanford immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that each subject needs to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted. If you have questions, please contact me at 408-924-2480.

Appendix B: Means and Standard Deviations of Pre-test and
Post-Test Vandenberg Scores

(standard deviations in parenthesis below means)

Pre-test Scores

<u>Handedness</u>	<u>Condition</u>			
	MR	PC	VB	CN
NonRight	<u>M</u> =14.0 (<u>SD</u> =6.48)	<u>M</u> =9.8 (<u>SD</u> =6.21)	<u>M</u> =12.3 (<u>SD</u> =4.52)	<u>M</u> =11.6 (<u>SD</u> =6.36)
Right	<u>M</u> =12.2 (<u>SD</u> =4.08)	<u>M</u> =14.1 (<u>SD</u> =4.79)	<u>M</u> =13.6 (<u>SD</u> =6.11)	<u>M</u> =12.0 (<u>SD</u> =4.55)

Post-Test Scores

<u>Handedness</u>	<u>Condition</u>			
	MR	PC	VB	CN
NonRight	<u>M</u> =14.6 (<u>SD</u> =6.62)	<u>M</u> =12.9 (<u>SD</u> =4.86)	<u>M</u> =15.1 (<u>SD</u> =3.70)	<u>M</u> =13.4 (<u>SD</u> =6.52)
Right	<u>M</u> =11.7 (<u>SD</u> =5.25)	<u>M</u> =15.1 (<u>SD</u> =5.02)	<u>M</u> =14.3 (<u>SD</u> =5.74)	<u>M</u> =16.1 (<u>SD</u> =2.69)

Appendix C: Edinburgh Handedness Inventory

Name _____ Gender M or F

Please indicate your preference in the use of hands in the following activities by putting + in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless forced to, put ++. If in any case you are indifferent, put + in both columns. Some of the activities require both hands. In these cases, the part of the task or object for which hand preference is wanted is indicated in brackets. Please try to answer all the questions, and only leave a blank if you have no experience at all with the object or task.

	Left	Right
1. Writing		
2. Drawing		
3. Throwing		
4. Scissors		
5. Toothbrush		
6. Knife (without fork)		
7. Spoon		
8. Broom (upper hand)		
9. Striking Match (match)		
10. Opening box (lid)		

Using the above handedness scale as the general basis for making your judgment (rather than writing hand alone) to

the best of your ability identify any members of your immediate natural (do not include step-family, adopted family members or half brother/sisters) family including parents and siblings based upon handedness: right, left or ambidextrous (able to use both hands with ease).

Check number of natural family members who are:

<u>Right Handed</u>	<u>Left Handed</u>	<u>Ambidextrous</u>
Mother _____	Mother _____	Mother _____
Father _____	Father _____	Father _____
Sister(s) _____	Sister(s) _____	Sister(s) _____
Brother(s) _____	Brother(s) _____	Brother(s) _____

Note: if anyone was forced to switch from being left- to right-handed when growing up, count them as ambidextrous.

Appendix D: Vandenberg Test of Mental Rotation

Name _____

F. Hand _____

Strategy _____

This is a test of your ability to look at a drawing of a given object and find the same object within a set of dissimilar objects. The only difference between the original object and the chosen object will be that they are presented at different angles. An illustration of this principle is given below, where the same single object is given in five different positions. Look at each of them to satisfy yourself that they are only presented at different angles from one another.

Below are two drawings of new objects. They cannot be made to match the above five drawings. Please note that you may not turn over the objects. Satisfy yourself that they are different from the above.

Now let's do some sample problems. For each problem there is a primary object on the far left. You are to determine which two of four objects to the right are the same object given on the far left. In each problem always two of the four drawings are the same object as the one on the left. You are to put Xs in the boxes below the correct ones, and leave the incorrect ones blank. The first sample problem is done for you.

Do the rest of the sample problems yourself. Which two drawings of the four on the right show the same object as the one on the left? There are always two and only two correct answers for each problem. Put an X under the two correct drawings.

- Answers:
- (1) first and second drawings are correct
  - (2) first and third drawings are correct
  - (3) second and third drawings are correct

This test has two parts. You will have 5 minutes for each of the two parts. Each part has two pages. When you have finished part I, STOP. Please do not go on to Part 2 until you are asked to do so. Remember: There are always two and only two correct answers for each item. Work as quickly as you can without sacrificing accuracy. Your score on this test will reflect both the correct and incorrect responses. Therefore, it will not be to your advantage to guess unless you have some idea which choice is correct.

DO NOT TURN THE PAGE UNTIL TOLD TO DO SO

GO ON TO NEXT PAGE

PART II

Appendix E: Strategy Instructions**Mental Rotation :**

In a few minutes I will be asking you to do the task again. My purpose is to see if performance can be improved by using a particular strategy. Look at the figure on the far left. This is called "the standard." Look at the standard figure and in your mind imagine it rotated or turned to a new position, similar to the position of the first test figure. Compare this rotated image of the standard figure against each of the test figures and check whether all blocks of both figures are in the same location. If so, mark that figure with an "X" in the box below that figure. Each time has two correct test figures. I am going to repeat these instructions.

Perspective Change Strategy:

In a few minutes I will be asking you to do the task again. My purpose is to see if performance can be improved by using a particular strategy. Look at the figure on the far left, this is called "the standard." the standard as well as each test figure should be thought of as stationary and cannot be moved. You are to imagine yourself going within the circle, once in the circle, position yourself at or near some point on the standard figure. Choose any starting point on the standard figure and imagine yourself moving through,

over, or around the standard figure noting the block configuration. Then place yourself at the same starting position on each test figure and compare to see if the block configurations correspond. If so, mark that figure with an "X" in the box below that figure. Each item has two correct test figures. I am going to repeat these instructions one time.

Orientation Free Strategy:

In a few minutes I will be asking you to do the task again. My purpose is to see if performance can be improved by using a particular strategy. Look at the figure on the far left. This is called "the standard". Look at the standard figure and locate some point on that figure, from this point describe the figure to yourself in terms of block configuration, for example up 4, left 2, back 3. Feel free to write on the instrument if you wish. Compare this description of the standard figure against each of the test figures and check whether all blocks of both figures are in the same location. If so, mark that figure with an "X" in the box below that figure. Each time has two correct test figures. I am going to repeat these instructions one time.

Control Group:

In a few minutes I will be asking you to do this task again. My purpose is to see if performance can be

improved by practice. Look at the figure on the far left. This is called "the standard." Compare the standard figure against each of the test figures and check whether all blocks of both figures are in the same location. If so, mark that figure with an "X: in the box below that figure. Each item has two correct test figures. I am going to repeat these instructions one time.

Appendix F: Questionnaire on ability to use instructed
method

Group Designation: R   NR
Strategy Condition: MR   PC   OFV   CN

Place an "x" on the line indicating your answer.

How well were you able to
use the strategy as   Very well<----->Not Well
instructed?
1....2....3....4....5....6....7

How difficult was it for   Least Diff<----->Most Diff
you to use the strategy to
select the correct choices?
1....2....3....4....5....6....7

How much of the time were you
able to use the strategy given
to determine the correct
choices?   100%....75%....50%....25%....0%

Where there some choices that
you were able to use the instructions
and others that you were able to use
them less well?   Yes   No

When not using the strategy as instructed, what type of
technique did you use to determine correct answers?
Describe below: