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SEX DIFFERENCES IN SPATIAL ABILITIES USING A DUAL CODING MODEL

by

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Abstract

SEX DIFFERENCES IN SPATIAL ABILITIES USING A DUAL CODING MODEL

by

Marie P. Weinstein

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This study represents an initial attempt to demonstrate that sex differences in spatial and verbal abilities can be explained in terms of Paivio's dual coding model of information processing: i.e., in terms of variations in the nature of the task (concreteness of stimulus items), and time allowed for information processing to occur. Paivio's model describes three types of processing: simultaneous processing of nonverbal or "spatial" information, sequential processing of verbal information, and dual processing of information which lends itself to both types of coding. The study employed a modified version of Paivio's dual coding experiment. Four sets of stimuli (abstract words, nonnameable geometric forms, concrete pictures, and nameable geometric forms) were visually presented to small groups of 99 male and 106 female technical college students. Each set of ten stimulus items was presented at a fast and slow rate (5 fast and 5 slow). Each item was exposed for .6 seconds. At the fast rate there was an inter-item interval of .23 seconds, at the slow rate the interval was 3.5 seconds. After viewing each set of stimuli, subjects completed a free recall or recognition memory test. The data were analyzed using analyses of variance procedures and _a priori_ contrast hypotheses were tested. The data involving the coding of purely verbal information produced the expected sex differences at the fast and combined rates. Data involving the processing of information which could be dually coded also produced sex differences in the expected direction. Data involving the coding of purely spatial information did not produce the expected sex differences. Thus, dual coding seems to provide an adequated model for explaining sex differences in the processing of "purely verbal" information. It also seems adequate for explaining sex differences in spatial abilities as long as verbal processing can occur. When the task does not permit verbal (sequential) encoding, dual coding seems insufficient to explain sex differences in processing. Implications of the results are discussed in terms of possible interventions to manipulate or eliminate sex differences.

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Introduction

There has been a well established interest in sex differences in cognitive functioning (e.g., Harris, 1978; Maccoby and Jacklin, 1974; Oetzel, 1966). Many sex differences have been broadly hypothesized, but research has generally indicated that differences exist in only two areas; spatial abilities and verbal abilities. Sex differences in verbal abilities, favoring females throughout the lifespan, have been widely reported in the literature (Burstein, Bank, and Jarvik, 1980; Oetzel, 1966). Although the results are less consistent for sex differences in spatial abilities, males have been found to have superior spatial abilities when compared to females. This inconsistency may be, at least in part, due to the lack of uniformity in defining spatial abilities. The question remains: what do these sex differences mean?

One possible explanation for these sex differences involves how these abilities have been measured. A variety of efforts, particularly factor analytic approaches, have been made to refine the measurement of spatial abilities (Burstein, et al., 1980; Freedman, 1979; Harris, 1978; Maccoby and Jacklin, 1974). However, these attempts have not clarified the source of these sex differences. Another approach to determine the source of these differences is to move from an ability description to an information processing one.

One existing information processing view of spatial ability that has potential for explaining sex differences is Paivio's dual coding theory. He has attempted to explain how information (spatial and verbal) is processed by varying task conditions. In addition, Paivio's model of dual coding is consistent with a physiological view that explains information processing in terms of cerebral hemispheric functioning. The important question is: can Paivio's model of dual coding capture and explain these sex differences--i.e., in spatial abilities, and secondarily in verbal abilities?

Sex differences

Sex differences in cognitive functioning have been the subject of widespread investigation (e.g., Burstein, et al., 1980; Fairweather, 1976; Freedman, 1979; Harris, 1978; Hutt, 1972; Maccoby and Jacklin, 1974; Ounsted and Taylor, 1972; Sherman, 1978). When sex differences were reported, females tended to achieve higher scores on measures of verbal abilities, and males tended to achieve higher scores on measures of spatial abilities (Burstein, et al., 1980; Harris, 1978).

In an extensive review of the literature on sex differences, Maccoby and Jacklin (1974) identified spatial abilities as one of the cognitive areas in which sex differences were found to exist. Nevertheless, they challenged the "folk" observation that "girls are auditory, boys are visual." They reported that no sex differences existed in infants' response to sounds or in their ability to fixate on visual stimuli. At most ages, the sexes were reported equally adept at discriminating speech sounds. No sex differences were found for memory for sounds as well. In addition, Maccoby and Jacklin concluded that, throughout the lifespan, the sexes are highly similar in their interest in visual stimuli, the ability to discriminate among visual stimuli, the ability to identify shapes, distance perception, and a variety of visual perception. However, other researchers have reported sex differences (e.g., Burstein, et al., 1980; Freedman, 1979; Harris, 1978; Oetzel, 1966).

Sex differences in verbal abilities

Reviews of sex differences in verbal abilities have been equivocal in reporting findings. Burstein et al., (1980) and Oetzel (1966) have reported consistent differences favoring females throughout the lifespan. Other reviews consistently found females to be more proficient beginning with adolescence (Droege, 1967; Eicchorn, 1973; Gallagher, 1964; Maccoby and Jacklin, 1974). In reviewing Maccoby and Jacklin's conclusions relating sex differences to individual differences (e.g., I.Q. scores), Plomin and Foch (1981) suggested that differences between groups appeared to be trivial compared to individual differences within groups. However, their review was based on sex differences in general, rather than a detailed evaluation of sex differences in verbal abilities.

Sex differences in spatial abilities

According to Harris (1978):

> ...the most persistent of individual differences on multifactor tests of psychological functioning is a sex difference in spatial ability. Males have decidedly better spatial skill than females. Indeed, on a number of tests, only 20% to 25% of females exceed the average performance of males (p.405)

Various measures of "spatial ability" have been used. Measures which have resulted in sex differences include: the Embedded Figures Test (Schwartz and Karp, 1967; Witkin, et al., 1967); problems involving three-dimensional kinetic imagery and rotation (Bennett, et al., 1959; Hartlage, 1970); mazes, form boards, block counting from the Differential Aptitude Test and from the Primary Mental Abilities Test; Block Design and Picture Assembly of the WISC and WAIS (Burstein, et al., 1980); knowledge of geometrical principles not involving mathematical or algebraic knowledge (Smith, 1964); chess playing (Chase and Simon, 1973); directional sense and orientation (Porteus, 1918; 1965); map reading (Money, et al., 1965); pattern walking (Keough, 1971); right/left discrimination (Bakan and Putnam, 1974); complex coordinations (Shepard, et al., 1962); the Rod and Frame Test (Fiebert, 1967; Morf, Kavanaugh, and McConville, 1971; Schwartz and Karp, 1967; Witkin, et al., 1967); geographical knowledge (Bettis, 1974); and Piagetian spatial tasks (Graves, 1972; Hooper, 1969; Liben, 1973; Thomas and Hummel, 1973; Tuddenham, 1970). Since all of these tasks are said to measure spatial ability, the question arises: what is meant by "spatial ability"?

In a discussion of sex and ethnic differences on a spatial perception task, Jahoda (1979) argued that "spatial ability" is not a single entity capable of being assessed equally well by means of quite different tests or tasks, as has been frequently implied. He suggested that this conclusion might explain the numerous inconsistencies and contradictions found in the literature. Jahoda (1979) demonstrated that ethnic and sex differences may be a function of the nature of the task.

Burstein, et al., (1980) also noted that the spatial abilities construct appears to encompass more than just one unique ability. They noted that the dilemma in reviewing this large body of data is that there have been no systematic comparisons made of the various measures of spatial ability to ascertain to what extent they correlate with one another.

In their discussion of sex differences in spatial ability, Maccoby and Jacklin (1974) divided tasks into two basic groups: analytic and nonanalytic. The nonanalytic category was said to tap "visual spatial abilities," and included tasks which primarily involved statis visual imagery. These tasks showed an advantage for males beginning between the ages of six and eight. The authors noted that few studies, however, use these tasks, which may explain the lack of correlation among various "spatial abilities." The authors concluded that tests lacking in analytical components demonstrate no sex differences until adolescence. This male advantage emerges in early adolescence and is maintained in adulthood for both kinds of tasks.

An interesting note to these findings was provided by Richmond (1980), who suggested that Maccoby and Jacklin's (1974) conclusion is not based upon a single study, but rather was drawn from a review of the literature concerning sex differences in spatial abilities. Consequently, Richmond attempted to directly answer the following questions: Are there sex differences? Are they consistent across a range of spatial tasks? He conducted a study in which six paper and pencil tasks were administered to preadolescent males and females. Consistent with Burstein, et al., (1980), Harris (1978), and Maccoby and Jacklin (1974), Richmond argued that tests of spatial ability do not display a simple and singular pattern of relationships. He identified two basic "space factors." They correspond to what Thurstone called Space (S1 factor), and Flexibility of Closure factor (C2 factor). The S1 factor was defined as "the ability to visualize a rigid configuration when it is moved into different positions" (Richmond, 1980). The C2 factor he defined as "the ability to keep in mind a configuration against distraction." Richmond's results provided evidence for sex differences on tests of the S1 factorial type, but not on tests of the C2 factorial type. He made little comment on this finding, except to say that sex differences in spatial abilities are not generalized in a preadolescent population. Another explanation might possibly be provided by Freedman's (1979) view of sex differences in spatial abilities.

Spatial abilities redefined as cognitive strategies

Freedman (1979) hypothesized that sex differences in spatial skills are a function of sex differences in cognitive strategy due to female developmental precocity in verbal skills. Freedman asked college students to fill out a questionnaire detailing the strategies they used in performing a mental rotation task. The expected sex differences were confirmed. Although the most frequently used strategy employed by both sexes was "mental picturing," females reported using significantly more verbal strategies than males, such as: "thought in words, talked to themselves." Freedman noted in her discussion that although the task was chosen specifically because it was "difficult to solve by use of verbal strategies," females reported that they did so. She suggested that there are relatively few so called spatial tests thought to be entirely free of linguistic mediation. She noted further, as did Eliot and Salkind (1975), that there may be a wide variety of cognitive strategies that employ some kind of verbal mediation in the solution of spatial tasks.

Similarly, Tapley and Bryden (1977) identified two distinct approaches to solving mental rotation tasks: "visual holistic" and "verbal analytic." They found that men relied upon a visual holistic strategy. Further, Wilson, et al., (1975) proposed that the magnitude of sex differences is particularly strong in spatial rotation tasks. These tasks would seem to put females at a greater disadvantage precisely because it is very difficult to employ verbal strategies.

Tapley and Bryden (1977) also reported sex differences in reaction time on the mental rotation task. Peterson and Wittig (1979) noted that measures of reaction time may help to differentiate verbal from nonverbal cognitive strategies, since verbal strategies normally take longer than "visual" or nonverbal ones. Similarly, in a study which investigated sex differences and pattern copying, Vasta, Regan and Kerley (1980) replicated a previous finding (Keough, 1971) that males make better use of visual reference cues for reproducing patterns. This finding suggests that males may be more likely to "code" visually than females.

Burstein, et al., (1980) offered similar findings as an explanation for the contradictory results in various studies of sex differences in spatial abilities. They suggested that performance on some spatial tasks can be mediated by verbal strategies. They specifically noted that females, who are known to score higher than males on tests of verbal ability, could actually be translating a seemingly "pure spatial task" into a verbal problem, thereby solving it in the way they know best.

McGlone and Kertesy (1973) investigated the patterns of hemispheric differences in males and females. They suggested that their findings, "provide new evidence that verbal processes may play a significant role in 'nonverbal' activities and that females make more use of such verbal mediation" (p.318). Their findings indicated that females use their left hemisphere and its analytical, sequential linguistic mode for solving spatial problems as well as for solving purely verbal problems. Thus, females become disadvantaged, in contrast to males, on various types of spatial problems, particularly if those problems are not amenable to verbal coding.

Although there is no evidence that directly supports the existence of sex differences in strategy preferences, there are data which indicate that females are more "verbal" in their problem solving, and that I.Q. in females proceeds on a course in which language plays a larger role than is true for males (Harris, 1978). Cameran, et al., (1967) reported that vocalization scores of infant females between five and thirteen months of age were correlated with I.Q. scores (Stanford-Binet) obtained when they were between six and 26. For females vocalization scores in infancy were positively correlated with I.Q. scores later in life. This was not true for males.

Moore (1967) reported similar results. Infant language scores (spontaneous babbling, and use of words) were highly predictive of later measures of "general intelligence" in females, but not in males. He concluded that females' intellectual development takes place primarily through linguistic channels, whereas in males nonverbal skills play a relatively more prominent role.

Consistent with the view that male and female intellectual development proceed along different paths, Hutt (1972) commented that: "...while boys are still concerned with active exploration of their environment and with perceptual and motor skills, the girls are becoming increasingly adroit in their verbal and social functions" (p.102). Sutton-Smith and Savasta (1972) similarly reported that by preschool age males prefer play that emphasizes exploration of objects, movement, strength, body contact, use of height and downfall, and greater range of movement and use of open spaces. Females' games are characterized more by singing, games with chants, sociability, verbal behavior and stasis. The two divergent "paths" of intellectual development and cognitive strategies characterize more than simply different approaches to problem solving. One theory which has accounted for differential processing strategies which might explain these two paths of intellectual development and problem solving is Paivio's information processing theory of dual coding.

Paivio's Dual Coding Theory

Paivio (1971) has proposed a theoretical framework in which he describes two kinds of information processing or encoding styles. Paivio distinguished between simultaneous (parallel) and sequential processing as two models of an information processing system. He saw them as distinct and separate modes of coding, which usually operate in conjunction with one another. One important determinant of the "preferred" mode of encoding or cognitive strategy is whether the task is a sequential one as opposed to one in which the elements are simultaneously given. In other words, whether the elements can be dealt with independently of each other is an important distinction between these two processing modes.

Elsewhere, Paivio also described the imagery and verbal systems as simultaneous and sequential processes (Paivio, 1977). In the imagery system, elementary images are organized into higher order structures so that the informational output of the system has a synchronous or spatial character. The verbal system is depicted as consisting of linguistic units which are organized into higher order sequential structures.

Paivio's dual coding hypothesis assumes that imaginal and verbal processes are differentially available as memory codes for abstract words, concrete words, and pictures (Paivio, 1971). The image code increases in availability as a representational response to words but is somewhat less available as a verbal referential (labeling) response to pictures. He supports these assumptions by discussing latency research regarding the arousal of the two processes (Paivio, 1971). These latency measures are particularly relevant to the rate of manipulation, which he introduced as one of the experimental variables in his "dual coding experiment" (Paivio and Csapo, 1969). He described this study as a "test of the model" (Paivio, 1971, p.234). His description included the distinction between sequential and simultaneous processing; i.e., the verbal system is specialized for sequential processing; the image system for parallel processing in the spatial sense. More recently, Paivio (1975; 1978; 1979; 1983) has preferred to express this distinction in terms of "synchronous and sequential processes, correlated with the contrast between analog and discrete representations" (Paivio, 1983, p.309). Otherwise, Paivio's position on the role of mental imagery in human memory has remained essentially unchanged (e.g., Paivo, 1978b; 1979).

The basic theoretical approach to Paivio's dual coding theory is that "images and verbal processes are viewed as alternative coding systems, or modes of symbolic representation" (Paivio, 1971, p.8). They are postulated as two basic "cognitive modes" (Paivio, 1971b) as "separate representational systems for nonverbal (the image system), and verbal (the verbal system) information" (Paivio, 1975). To be specific, Paivio (1979) stated:

> The theory assumes that cognitive behavior is mediated by two independent but richly interconnected symbolic systems, which are specialized for encoding, organizing, transforming, storing and retrieving information. The *image* system is specialized for dealing with perceptual information concerning nonverbal objects and events. The other (the *verbal* system) is specialized for dealing with linguistic information. The systems differ in the nature of the representational units, the way in which the units are organized into higher order structures, and the way the structures can be reorganized or transformed (p.48).

In another article, Paivio (1975) distinguished "the verbal system as an abstract, logical mode of thinking as compared to the concrete analogical mode that apparently characterizes imagery." To oversimplify: visual imagery is regarded primarily as a parallel (synchronous) processing system, specialized for storage and symbolic manipulation of information concerning spatially organized objects and events. The verbal system, by virtue of its auditory/motor nature, is specialized for sequential processing as in serial memory tasks (Paivio, 1971).

There are several important ways in which the two hypothesized systems are assumed to differ. Recently, Paivio (1978) has discussed assumptions of his model. The most important assumption is that of the "independence/interconnectedness of the two systems." Each is assumed to function independently and thus, both systems can be experimentally manipulated in isolation of one another. However, they are always assumed to be interconnected. It is more typical that the two systems interact in a particular situation. Paivio (1975b) viewed this interdependency as so high that "whether these are regarded as distinct symbolic systems or as two kinds of sub-processes within a single system is probably irrelevant in a formal sense."

Coding Processes and Levels of Meaning

Paivio (1971) presents a theoretical analysis of the levels of meaning and the nature of the coding processes at each of these levels. All theories of coding assume that incoming stimulus information is transformed and elaborated within the organism (Richardson, 1983).

The initial (preprocessing) level of stimulus processing in Paivio's model is the sensory storage system, which is assumed to retain relatively untransformed information for a brief period following stimulus presentation. These sensory storage systems (visual and verbal) are not related to meaning. All further levels do involve processes that are hypothetically linked to meaning. Each level involves either imaginal or verbal symbolic processes, or both, and applies to nonverbal as well as verbal stimuli.

The first level is the representational level, where the sensory trace produced by a stimulus when it is perceived arouses the appropriate symbolic representation in long term memory; thus, words activate verbal representation, and visual perceptual experiences activate imaginal representations. In other words, these are the symbolic representations stored in long term memory as concrete memory images in the case of objects, and as implicit auditory motor representations in the case of verbal stimuli. At this level, objects and words (nonverbal and verbal) as stimuli simply activate the corresponding representational processes within the individual. The second is the referential level, where symbolic representations in one system may arouse corresponding representations in the other system: these interconnections are involved in naming objects or describing images, and in generating the image of an object when given its name. In other words, their referential meaning level refers to the first level of associative reaction. This presumably requires the establishment of a connectedness between the representational image and the representational verbal process corresponding to a particular concept. For example, an object or a picture evokes its implicit or explicit verbal label, and a verbal stimulus may evoke the corresponding representational image. Finally, the third, or associative level involves associative connections among imaginal or verbal representations, or both.

Whether the processes at any of these three "levels of processing" or "levels of meaning" are involved in a given psychological task is assumed by Paivio (1971) to depend upon particular characteristics of the task; this assumption gives rise to various empirical hypotheses concerning the effects of imaginal and linguistic variables in different experimental situations (Paivio, 1971, 1972).

Another major assumption about the differences in the two systems is that they are different in the way in which their units are organized into higher order structures. The imaginal system is assumed to represent information in a synchronous or spatially parallel manner, so that different components of a complex object or scene are simultaneously available. On the other hand, the verbal system is taken to employ the sequential organization which is characteristic of linguistic utterances. Similarly, the imaginal system is assumed to be capable of transformations along spatial dimensions (i.e., size, shape, and orientation), whereas the verbal system allows transformations on a sequential frame (i.e., additions, deletions, and changes in sequential ordering).

The Dual Coding Paradigm

Paivio (1971; Paivio and Csapo, 1969) conducted numerous studies on the nature of dual coding. In his general discussion of experimental approaches to dual coding, he included three variables: 1) stimulus characteristics, with particular emphasis on their abstractness/concreteness and verbal associative meaning; 2) experimental manipulations, such as different task instructions, presentation rates, and task demands; and 3) individual differences in imaginal and verbal associative abilities (Paivio, 1971). He proposed these variables as affecting the availability or accessibility of the symbolic systems in a given task. Overt behavioral effects and psychological reactions are, in turn, predicted from the independent variables.

The two memory codes, according to Paivio (1971) cannot be identified in a simple and direct manner with traditional sensory channels. The image code is visual in the studies considered, but it is specific for nonverbal information, not visual word images. Conversely, the verbal code cannot simply be equated with the auditory modality, although that modality may be an important component of the verbal system.

Tests of the Dual Coding Model

The implications of Paivio's theoretical analysis were tested directly by varying the availability or accessibility of the two memory codes, along with the necessity of sequential processing in the memory task (Paivio and Csapo, 1969). Abstract words, concrete words, and pictures were used as stimuli. Availability was manipulated by varying stimulus concreteness and rate of presentation. In this experiment, Paivio operationalized "dual coding" by controlling rate of presentation of stimuli and stimulus type. The fast rate was hypothesized to interfere with the arousal of referential or associative images to words. Thus, under the fast rate of presentation, the stimuli more or less determined the mode of coding. "Dual coding" could occur only at the slow rate and with certain stimuli. Paivio found the rate effect was significant overall. A double interaction of rate by stimulus attribute indicated that the effect was clearly greatest for pictures (which could be dually coded) and least for abstract words (which could only be coded by way of the verbal system).

In the second part of his experiment, Paivio investigated the number of new items correctly recognized as new. This involved a recognition memory task in which the number of new items correctly recognized was separately analyzed as a function of stimulus attribute and rate. According to Paivio (1971) results indicated that pictures were superior to words at both the fast and slow rate. He presumed the verbal code to be unavailable for pictures presented at the fast input rate. He interpreted his finding as providing strong evidence that some aspects of stimulus information are better retained in the visual image code than in the verbal memory code. This last conclusion, however, was an afterthought.

The Concreteness/Abstractness Dimension

Paivio's theoretical assumptions are partially concerned with the differential availability of images and verbal processes as a function of the concreteness dimension (Paivio, 1971). Pictures, if familiar and easily named, are meaningful both at the representational and the referential levels, i.e., they readily arouse both a concrete memory representation (image) and a verbal label. The more concrete or "thing-like" the stimulus or the task situation, the more likely it is to evoke memory images that can be functionally useful in mediating appropriate responses in that situation. Both symbolic modes are readily aroused and can be useful when the situation is relatively concrete.

According to Paivio (1971) verbal processes will be differently favored when the situation is relatively abstract. This point of view does not take into account situations which are "nonverbally abstract." Paivio (1971) stated, "Many situations likely involve an interaction of imaginal and verbal processes, however, and the latter would necessarily be involved at some stage whenever the stimuli or responses, or both, are verbal..." (p.9). But what about a situation in which the stimuli and task requirements are not verbal, and in which both processes may not be involved? Paivio did not consider this directly.

Concreteness/abstractness is traditionally defined in the psychological literature in three ways, all of which share a common core of meaning (Paivio, 1971). First, it is defined as a characteristic of stimuli, especially words. This refers to the directness with which the stimulus denotes particular objects, and is equated with the specificity/generality of terms (Brown, 1958). Second, it is used to refer to task characteristics, implying stimulus/response relations (from the dictionary definition "take from"). Third, concreteness/abstractness can be defined in terms of the psychological characteristics or reaction tendencies in the individual (Paivio, 1971). As Paivio succinctly puts it:

> Like imagery, verbal thought remains functional in coping with concrete situations but surpasses imagery in its capacity to deal with abstract tasks requiring the manipulation and integration of spatially and temporally remote objects or events, or tasks involving abstract reasoning. Not to be taken as a rigid dichotomy of symbolic modes, for it will be suggested that imagery, too may be abstract and schematic and that it apparently can serve abstract functions...(p.18)

Although Paivio did not concern himself experimentally with abstract aspects of imagery, he theoretically acknowledged its existence and importance. Another way of viewing the task definition of concreteness/ abstractness is that abstraction requires the manipulation of spatially temporally remote events, i.e., not simply storing events in memory, but manipulating the symbolic components (along with concrete aspects of the task which confront the individual) in the interests of the demands of the situation.

Another aspect of the abstractness of spatial nonverbal elements discussed by Paivio (1971) involved the study of chess players. Particularly significant is the reported observation that the imaginal representation of the chess board decreases in clarity of detail as the player's experience and proficiency increases. A shift toward abstractness of imagery proceeds as the proficiency of the player does. The good chess player's visual image utilized a visual memory that "lacks...concrete pictorial quality. Though visual, it is an abstract kind of memory...a geometrical memory."

Abstractness/concreteness has been considered by many cognitive theorists in a nonverbal sense, although this aspect of the dimension seems more difficult to describe and capture than the verbal abstract/ concrete dimension (Attneave, 1957; Humphrey, 1951; Woolworth, 1938).

Ernest, who worked with Paivio (e.g., Paivio and Ernest, 1971), attempted to place her research within the theoretical framework of "Paivio's dual coding approach to memory and cognition" (Ernest, 1983). She stated that the verbal system is specialized for dealing with "abstract information such as language" (p.1). She, in essence, equated abstractness with verbal processes, precluding a "nonverbal" dimension of abstractness. She further stated, "the specialization of the imagery system is processing concrete perceptual information, such as nonverbal objects or events" (p.1), equating the nonverbal with the concrete. This seems a narrow view of abstractness/concreteness; a view not shared by other cognitive theorists (Attneave, 1957; Humphrey, 1951; Werner and Kaplan, 1963).

Indeed, Richardson (1980) presented experimental evidence that imageability predicted performance on abstract but not concrete items. This suggests imageability and concreteness are not necessarily synonymous. Ernest, on the other hand, defined imagery ability as the "individual differences counterpart of the imagery symbolic system" (p.1) and goes on to define imagery and measure spatial ability in the same narrow terms (1980). In using "visualization" tests to index imagery ability she seems to be looking at only one limited aspect of spatial ability. She experimentally limits her focus to the perceptual aspects of imageability. Processing and encoding of information involve much more than the perceptual representation aspects of imageability, as does concreteness/abstractness.

Like Ernest, Paivio (1971; Paivio and Csapo, 1969) investigated abstractness of materials only in the verbal dimension. He did not attempt to operationalize "visual" or nonverbal abstractness in his dual coding study.

Whitehouse (1981) used Paivio's model of dual coding to investigate right/left hemispheric function in unilaterally brain damaged patients. He linked the two models of processing with a cerebral hemispheric functioning model. Although he included in his study stimulus materials he describes as visually abstract, he did not discuss the theoretical implications of these materials on dual coding theory. In fact, his results were somewhat equivocal.

Contrary to his expectations. Whitehouse found that left hemispheric damaged patients improved their performance on the "abstract" picture stimuli task, given additional time. Abstract pictures were constructed from a nameable picture by preserving the basic form and details but by rearranging features as necessary to make the picture unidentifiable and thus unnameable. He presumed that the "complexity" (of lines and angles) of the abstract pictures he used effected the difference in performance. Additional time permitted encoding of more aspects of the primary imaginal code. Right hemisphere damaged patients did not profit from the extra time. This finding might be more a function of working with brain damaged patients, who have difficulties with conceptual "abstractness" and processing of information in general, no matter which hemisphere is involved, and who may have compensated for their deficits in another way.

Another explanation rests with the possibility that his stimuli were not truly "abstract." Paivio (1971) described concrete stimuli as more featurally distinct and detailed than abstract stimuli. The more concrete a stimulus is, the more detail is noted--and therefore the more easily processed. Thus additional time would allow for processing of spatial details to occur (in left hemisphere damaged patients, who still had their right hemisphere ability intact). Thus, Whitehouse's pictures were simply more spatially complex, not necessarily more "abstract." It is the essence of abstractness that there is a "thriftiness" of detail. For example, a photograph, with more detail, is more concrete than a line drawing (Paivio, 1971). The "complexity" involved in abstractness, therefore, is not complexity of line and angle, but conceptual complexity. To capture the dimension of abstractness one has to look further than complexity of line.

Synchronous and Sequential Processing in the Dual Coding Model

Synchronous (simultaneous) and sequential processing are basic assumptions of the dual coding model. Paivio (1971; Paivio and Csapo, 1969) equated specific tasks with each of these two processes. He designated memory span and serial learning tasks as sequential order tasks, and equated them with the verbal sequential coding system. Recognition memory and free recall tasks are designated as synchronous (simultaneous) processing tasks which do not involve sequencing. These tasks are equated with the synchronous coding system.

Problems with the Dual Coding Research

Paivio (Paivio and Csapo, 1969) did not test for the "verbal" sequential code primarily by using verbal stimuli and verbal responses, and manipulating these variables. Instead, he operationalized the two types of processing in terms of the type of task. He seems, therefore, to be defining the concept by the procedures, and not by the stimulus and response variables. By using one to define the other, he seems to be confusing his dependent with his independent variable. Having items remembered in sequence seems a simplistic method of operationalizing a concept as complex as sequential processing. His definition of the concept seems to be confused with how it was measured.

In order to measure verbal sequential processing of verbal materials, stimulus and response modes should be manipulated. Paivio seemed to focus on the product rather than the process by equating the task with the kind of processing to operationally define sequential and synchronous processing.

Paivio experimentally addressed the importance of varying stimulus type only indirectly by investigating the abstract/concrete dimension (Paivio and Csapo, 1969). He equated "abstract" with verbal, and "concrete" with nonverbal. In this original study, which tested the dual coding model, Paivio was primarily concerned with the verbal sequential coding system (Paivio and Csapo, 1969). It is only in passing that he focused on the type of code and stimulus information itself (Paivio, 1971). He operationalized this by analyzing performance on a recognition memory task as a function of stimulus attribute and rate of presentation.

Another problem with Paivio's methodology is that requiring subjects to verbally name items as their response on the dependent measure seems to be confounding results. By asking subjects to "name" the visually presented pictures, Paivio was, in essence, forcing them to "dually" code that information. Since it was specifically dual coding which he was attempting to measure (Paivio and Csapo, 1969), this procedure renders his results somewhat ambiguous.

Ernest, who conducted studies which focused primarily on perceptual processing and imagery ability, seemed to be peripherally aware of this problem (Paivio and Ernest, 1971; Ernest, 1983). She noted (Ernest, 1983) that in her work, stimulus mode, per se, did not seem to be the primary source of inconsistency in the differential pattern of effects found between imagery/picture and imagery/words. The context within which the stimuli were presented was viewed as a more important variable than the mode of stimulus presentation. "Contexts that permit the 'expected' processing strategy to be primed--'expected' meaning congruent with stimulus mode" (Ernest, 1983, p.4) yielded the most unambiguous results. Imagery ability/picture effects emerged when a nonverbal processing strategy was prompted by the task requirements. Ernest (1983) believed "context" should be considered from the perspective of experimental design. This view that "context" can modify one's processing strategy has been supported by many others as well (Gooden and Baddeley, 1980; Stanovich and West, 1979).

To study spatial processing one should "prime" the processing strategy by keeping the stimulus mode, context, and presumably, the response mode, congruent. This was not the case in Paivio's original dual coding study (Paivio and Csapo,1969). Interestingly, this was also true of some of Ernest's work (Paivio and Ernest, 1969; Ernest, 1983). In a study involving right visual field (RVF) and left visual field (LVF) presentation of nonverbal stimuli, Ernest found a bias favoring the RVF (left hemisphere) among several high spatial imagers. This was quite the opposite of what one would expect, given the body of brain lateralization literature (Ernest, 1983). Ernest indicated an awareness that she may have "mixed" contexts (did not keep the stimulus mode constant with the response mode) when she noted the following:

> ...we know that the language production systems are localized in the left hemisphere of right handed individuals. Because all tasks described here require some form of verbal output, it seems reasonable to infer that the readier access of left hemisphere encodings to the left hemisphere language production center resulted in the 'favoring' of RVF presentation. (p.25)

Because Ernest (1983) used a verbal response mode in her RVF/LVF model, this "problem" may call into question many of her conclusions.

Another difficulty with Paivio's original dual coding study (Paivio and Csapo, 1969) is that all independent variables were presented to separate groups of subjects; therefore, intra-individual differences across the several tasks, and the effect of several task variables were not investigated. Statements made about the results cannot be widely generalized because the groups were independent. The differences found could theoretically be attributed to individual differences among group members. Although he did consider individual differences in a subsequent study, in the form of imagery ability (high and low imagers), this study did not employ a dual coding paradigm (Paivio and Ernest, 1971). The same criticism, using independent test groups, can also be applied to Ernest's work (Paivio and Ernest, 1971; Ernest, 1983). She concluded that by using only one type of stimuli for each study with independent groups, she was avoiding "priming" or carry over effects from other stimulus types. For each of her studies, therefore, she too used different stimuli, different subjects (with only two groups overlapping), and different response modes (Ernest, 1983). A within-subject research design would control more adequately for individual differences while also controlling for sequence effects (order effects [Tuckman, 1972]). Statements made about task differences can be stronger and more generalizable when tasks are presented to the same group of individuals.

Although there are difficulties in the methodologies employed by Ernest, she, nevertheless, attempted to examine sex differences and hemispheric functioning within the framework of a dual coding paradigm.

Ernest's Framework of Hemispheric Functioning

Ernest's work involved the study of perceptual processing of information. In an article dealing with spatial imagery ability, sex differences and hemispheric functioning, Ernest (1983) attempted to integrate imagery ability with visual perception of both verbal and nonverbal stimuli. She reported the results of a series of four unpublished studies which were an outgrowth of an original study performed with Paivio (Paivio and Ernest, 1971). From the collective data of these studies, Ernest (1983) constructed a proposed framework of hemispheric functioning for males and females, based primarily on the results obtained from research which inferred hemispheric differences from visual perceptual field stimulation.

Interestingly, Ernest (1983) presumed a broader scope to her findings than simply perceptual processing. She discussed her findings, comparing Paivio's symbolic systems with counterparts in the neuropsychological literature on lateralization of brain function. Ernest cited studies using both brain damaged and normal populations as suggesting that "the left hemisphere of the brain is specialized for verbal/linguistic/analytic functions whereas the special skills associated with the right hemisphere pertain to nonverbal/spatial information processing as well as global/holistic modes of analysis" (Ernest, 1983).

While Ernest stated that imagery and perception tap "similar" underlying processes, she did not carry this distinction far enough. She seems to assume that perception and encoding capture one and the same process. Ernest (1983) experimentally studied perception using a right visual field (RVF) and a left visual (LVF) model. She, in turn, made assumptions about the "processing" and "encoding" of information based on her observations of perception. Perception and encoding are undoubtedly related, but perception does not encompass the encoding process as a whole, and cannot be assumed to be identical to encoding.

In his original dual coding study (Paivio and Csapo, 1969), Paivio's design manipulated dual coding by varying the rate of presentation of visual stimuli. Dual coding was assumed unable to occur at the fast rate because it prevented the arousal of referential or associative images. These images are assumed to play an important part in the encoding process as a whole.

Ernest's work lacked some basic elements present in Paivio's dual coding model, and therefore failed to tap the encoding process as a whole. Her design failed to do so by: a) dealing with only perceptual processing of information; b) not employing a varying rate of presentation of stimuli (which is how Paivio operationally defined dual coding); and c) using recognition tasks instead of memory tasks.

Ernest's work dealt only with perception, which does not involve either the referential or associative levels of processing. She was therefore unable to capture encoding at these levels; nor did Ernest vary the rate of presentation of stimuli. In addition, all of Ernest's studies (Ernest, 1983; Paivio and Ernest, 1971) used recognition tasks as opposed to recall tasks. This procedure falls short of tapping the true "full" processing of information (no transformation of stimuli occurs). Paivio's original dual coding model employed memory tasks in order to tap into the encoding process. Since Ernest used tasks which involved the simple perceptual recognition of stimuli, her work did not deal with the encoding process as a whole.

Cognitive Strategies Preference and Cerebral Hemispheric Functioning

A major difficulty with Ernest's work (1983) is that she seems to define hemispheric coding preference by hemispheric efficiency for processing of perceptual data; a paradigm which precludes "choice." Richardson (1978) strongly emphasized the importance of experimentally capturing preference for coding in his discussion on mental imagery and spatial ability research. He states:

> A possible conclusion is that neither subjective nor objective tests of imagery ability are appropriate measures of the critical dimensions on which subjects vary in their use of different modes of symbolic representation. In studying individual differences in memory coding, I would suggest that the crucial question is not how well subjects employ a given mode of symbolic representation but which is the preferred mode of representation. We should therefore not be interested in the ability to construct and manipulate mental images, but in the preference for mental imagery as a mnemonic code (Richardson, 1978, p.133).

Ernest (1983) has not included encoding "preference" in her experimental design. The presentation of stimuli to the RVF or LVF in itself determines which hemisphere and/or encoding method will predominate.

Ernest seemed aware of this problem herself when she stated: "general modes of cognitive functioning may prove to be an over-simplification of reality. Individual differences must be considered because all individuals do not approach the same task in the same way. Secondly, a relationship exists between ability and strategy. That is, the effectiveness of a given strategy depends on one's pattern of abilities" (p.8).

Bryden (1979) suggests that males and females use different strategies in performing "lateralization" tasks. There is evidence from other sources, as well, that the sexes differ in their approach to the same task (Allen and Hogeland, 1978; Freedman and Rovegno, 1981; Kail, Carter and Pellegrino, 1979; McGlone, 1981; Tapley and Bryden, 1977). These different approaches and strategies have been linked to cerebral hemispheric lateralization (right hempisphere--spatial, nonverbal, global/holistic processing, and left hemisphere--verbal, linguistic, analytical processing). It has been argued that asymmetries in performance on hemispheric tasks may be reflections of attention (Kinsbourne, 1970; Young and Elles, 1981) and strategy choices (McGlone, 1980) rather than "true" differences in brain specialization. While Ernest mentions these constructs in her discussion, she experimentally ignores them by precluding an element of choice and limiting her focus to the study of perceptual processing.

In summary, encoding preference may be captured by allowing subjects to "choose" the processing strategy which is most efficient for them by employing a dual coding model. A model which allows for the dual coding of stimuli presents an opportunity for either or both encoding "strategies" to be used. Although Ernest attempted to place her work within the context of Paivio's dual processing theory, her work differed in several important ways from Paivio's original dual coding paradigm. Ernest's work did not truly capture the dual coding paradigm since she: 1) dealt only with perception; 2) did not vary the rate of presentation; and 3) did not use a memory task.

Simultaneous and Sequential Processing and the Cerebral Hemispheres

Other authors have attempted to link cognitive strategies with cerebral hemispheric differences and their specific processing modes. Most of the literature described the two distinct modes of coding operation in terms of assigning each specifically to a single hemisphere of the brain (Bogen, 1969; Levy-Agresti and Sperry, 1968; Nebes, 1974; Russell, 1979; Zangwill, 1960).

The left hemisphere is said to operate in a more logical, analytic computer-like fashion, analyzing stimulus information input sequentially, abstracting out the relevant details to which it attaches verbal labels. The right hemisphere, on the other hand, is seen primarily as a synthesist, more concerned with the overall stimulus configuration, and organizing and processing information in terms of gestalts or wholes (Bogen, 1969, Levy-Agresti and Sperry, 1968; Zangwill, 1960).

Das, Kirby and Jarmon (1979) described the two types of processing as follows:

> Simultaneous integration refers to the synthesis of separate elements into groups. These groups often taking on spatial overtones. This essential nature of this sort of processing is that any portion of the result is at once surveyable... Successive information processing refers to processing information in a serial order...In successive processing the system is not totally surveyable at any point in time. (pp.49, 50).

Information can undoubtedly be coded in memory either verbally or visually (e.g., Bower, 1972; Conrad, 1964; Posner, et al., 1969). Studies of hemispheric functions have also shown that the same information can be processed either through a left or right hemispheric mode (via sequential or simultaneous processing), depending on the presentation of the material (Bryden and Allard, 1976), or the instructions to the subjects (Geffen, et al., 1972; Seamon and Gazzaniga, 1973). Other researchers have stressed that verbal coding and verbal rule learning play an important role in general cognitive analysis (Beilin, 1971).

Levy-Agresti and Sperry (1968) proposed even further a "basic incompatability of language functions on the one hand and synthetic perceptual functions on the other" (p.1151). From an evolutionary perspective, they proposed that the left hemisphere would be "inadequate for the more rapid complex synthesis achieved by the right hemisphere" (p. 1151). It is on this supposition that they formulated a possible basis for cerebral lateralization in humans. Their hypothesized consequence of an analytic and synthetic gestalt perceptual incompatability is that during the evolution of the hominids, gestalt perception lateralized into the "mute" (right) hemisphere. Regardless of the basis for cerebral lateralization of function, there is a significant body of literature supporting its existence. This distinction in lateralization of functioning has been associated with the two types of processing (simultaneous and sequential). In addition, both cerebral lateralization of functioning and preferred mode of information processing have been linked to performance differences between males and females.

Clinical Evidence for Cerebral Lateralization of Functioning

Most of the evidence gathered to support lateralization of cerebral function has involved studying patients with brain injury or other cerebral trauma. These data have provided a picture which describes damage to the left hemisphere (especially in right handers) primarily as disturbing linguistic functions. Depending on the site of the lesion, it might include one or all of the following: difficulties in language comprehension; difficulties in expressive language (such as aphasia); reading difficulties; word finding problems (anomia); difficulties with mathematical operations (dyscalculia); writing difficulties (dysgraphia); and sensory motor problems on the contralateral side of the body (Paivio and deLinde, 1983).

Damage to the right hemisphere, on the other hand, is characterized as manifesting deficits in visual agnosia; somatagnosia, unilateral neglect; prosopagnosia (nonrecognition of faces); and constructional apraxia (Paivio and deLinde, 1983). Additionally, studies of right brain damaged patients have detected problems in integrating fragmented shapes (Nebes, 1972); failure at maze learning (Corkin, 1965; Milner, 1965); difficulties with the deduction of spatial relationships utilizing a series of complex patterns (Carmon, 1978); problems with recognition of melodies and emotional, nonverbal human sounds (Carmon and Nochshon, 1971; Kimura, 1964; Shankweiler, 1966); problems in detection of depth (Benton and Hecaen, 1970); failure to distinguish line orientation and directionality (Benton, et al., 1973) and poor recognition of abstract forms (Rubino, 1970). However, some researchers have argued that this pattern of deficits (and abilities) may not be the same for males and females (Bryden, 1979; Harris, 1978; McGlone, 1980; Witelson, 1976).

Sex Differences in Cerebral Hemispheric Functioning

To briefly sum up, sex related differences in brain asymmetry stemmed from evidence that, by adolescence, the sexes apparently differ in certain cognitive abilities. Males typically demonstrate superior spatial manipulation skills (Burstein, et al., 1980; Harris, 1978; Maccoby and Jacklin, 1974) and females excel in linguistic tasks such as verbal fluency (Burstein, et al., 1980; Fairweather, 1976; Freedman, 1979; Harris, 1978; Macaulay, 1978; Maccoby and Jacklin, 1974). Speculation concerning the sources or determinants of these differences led to an examination of sex differences in brain organization. Various other explanations, which are not mutually exclusive, have also been offered to account for the differences that exist between male and female performance in the two skill areas.

A review which examined the current thinking would have to include some combination of the following: a genetic explanation which sees spatial ability as inherited through a recessive sex-linked gene; an explanation involving the influence by various sex hormones, which are thought to act as releasing mechanisms, which differentially influence the neural substrate of the cerebral hemispheres, and an explanation which looks to environmental factors as playing a role in the enhancement or suppression of the manifestation of the two skills (Burstein, et al., 1980; Harris, 1975; Maccoby and Jacklin, 1974). The present discussion will address cerebral organization (hemispheric functioning) only.

The study of cerebral organization and sex differences in hemispheric functioning necessitated the use of various techniques (McGlone, 1980). The findings of such a wide range of studies have been reviewed by Bryden (1979) and McGlone (1980), who concluded that when sex differences are found, males tend to be more lateralized for verbal and spatial functions than females. However, "more is known of sex differences in language representation than those in spatial representation" (McGlone, 1980). Basically, this view seems consistent with the view that bilateral representation of language (especially in women) interferes with spatial processing (Harris, 1975, 1978; Levy, 1969, 1974). Spatial processing is presumed to be the province of the right hemisphere. The various research findings in this area have generated several models within a neuropsychological framework to explain these sex differences.

Neuropsychological Theories of Sex Differences

To comprehend the nature of differences between normal males and females in hemispheric functioning, several neuropsychological models have been proposed (Harris, 1978). These models are often complementary to one another, but at times differ primarily in points of emphasis rather than being mutually exclusive. There are three basic models which consist of: 1) earlier right hemisphere lateralization of spatial function in males; 2) earlier, greater left hemispheric language lateralization in females and bilateral spatial representation in males; 3) greater lateralization of function in males and bilateralization representation of verbal function in females.

Greater Lateralization of Function in Males and Bilateralization Representation of Verbal Function in Females

Although the literature is somewhat equivocal, one widely supported model proposes that, in adulthood, language function in females is bilaterally represented while the male brain becomes even further lateralized for language and spatial functions. This third model ascribes female spatial disadvantage to bilateralization of language function.

Levy (1969; 1972) and Sperry (Levy-Agresti and Sperry, 1968) are among the chief proponents of this model. According to this model, there is a basic incompatability in left and right hemispheric functioning (analytical, language function versus synthetic, perceptual functioning) which accounts for lateralization. Harris (1978) noted that genetic factors, during the pre and postnatal development period, predispose each neural blueprint to seek control of organization for its own hemisphere and the other. He quotes Levy as explaining:

> If the verbal blueprint wins, then the language dominant hemisphere is fully and appropriately organized for verbal function, but the nondominant hemisphere also is partially organized for verbal functions, so that this hemisphere's organization is, to some extent, misappropriately designed for spatial functions. Such people will manifest perceptual spatial deficits...because the neural organization within this hemisphere is incompletely developed to serve spatial functions. (p.464)

Levy's neuropsychological model of sex differences really consists of two parts. The first part asserts bilateral verbal function in females. The second part involves greater lateralization of function in males.

Bilateralization of language function in females

The largest body of evidence seems to support this model. According to Lake and Bryden (1976) there is little evidence indicating that language disturbance after left hemisphere injury is less severe and of shorter duration in females than in males. Nevertheless, they noted further that the overall number of reported cases of profound aphasia in females is very small. This would indicate that, for females, language function is bilaterally located since even with left (or right) hemispheric damage females do not seem to profoundly lose their language ability. In her study, which found aphasia associated with left hemisphere damage occuring three times more frequently in males than females, McGlone (1977) concluded that sex differences exist in the degree of bilateralization of language function, and that males were more lateralized (for language function) than females.

In addition, evidence indicating differential patterns of deficits in males and females after brain injury (Lansdell, 1961, 1962; Bogen, 1969; Bogen, DeZure, Tenhouten and Marsh, 1972; McGlone and Kertesz, 1973) have supported this model, as have dichotic listening studies (Bryden, 1966; Harshman and Remington, 1976; Lake and Bryden, 1976) and tachistoscopic measures (Ehrlichman, 1971; Hannay and Malone, 1976). Hannay and Malone (1976) presented a verbal memory task to both sexes and found no visual field differences in females, but right visual field (left hemisphere) superiority in males. They concluded that, in females, both hemispheres "receive and retain verbal information equally well."

Greater Lateralization of Function in Males

A corollary to Levy's (1972) position (bilateral representation of language function in females) would be that, in males, functioning is more lateralized than in females, although Levy did not directly emphasize right hemispheric spatial functioning in her work. She did not consider sex differences in lateralization of visual spatial functioning per se. Instead, she assumed that, in females, the spatial holistic processing of the right hemisphere was interfered with because language function was partially located there, as well as in the left hemisphere. Clinical evidence with brain damaged patients has provided a good deal of support for greater male lateralization of both functions in general, and spatial functions specifically (e.g., Bogen, 1969; Bogen, DeZure, Tenhouten, and Marsh, 1972; Lansdell, 1962; McGlone, 1977; McGlone and Kertesz, 1973).

Intra-Hemispheric Differences in Males and Females

One possible explanation for finding greater lateralization in males may be that, as McGlone (1977) and Kimura (1966) have suggested, intra-hemispheric difference may exist as well as inter-hemispheric differences. Two studies were conducted which employed analysis of EEG (electroencephalographic) activity during the performance of several tasks (Ray, Morrell, Frediani and Tucker, 1976; Tucker, 1976). Ray et al., (1976) compared male/female EEG recordings while subjects performed four left hemisphere tasks (adding numbers, counting verbs in sentences, constructing sentences, multiplication) and four right hemisphere tasks (visualization in two different activities, and listening to two kinds of music). Results supported greater male lateralization of function. Males tended to use their left hemispheres for left hemispheric tasks, and their right hemispheres for right hemispheric tasks; females did not demonstrate significant lateralization of function.

Tucker (1976) examined sex differences on two visuospatial tasks (Gottschaldt Embedded Figures Test and Mooney Closure Faces Test) and a vocabulary task. Tucker proposed that the Embedded Figures Test required an analytic, part-whole understanding of relationships more characteristic of left hemispheric processing, while the Closure Faces Test was assumed to capture the synthetic, global processing characteristic of the right hemisphere. Overall findings indicated sex differences on all three tasks. Males showed significantly more activity in the posterior region when performing the Closure Faces Test (synthetic, right hemispheric type processing). For the Embedded Figures Test (analytic, left hemispheric type processing) males relied as much on their left hemisphere as they did on the vocabulary test. Finally, males and females did not use the same regions within a hemisphere for solving the Embedded Figures Test or the vocabulary tests.

Tucker concluded that males are more lateralized for some spatial tasks and for some verbal tasks. He noted: "Apparently it is predominantly synthetic visuospatial functions for which the right hemisphere is specialized in males...and the left hemisphere is more specialized in males than females for at least some kinds of verbal processing" (1976, p.452). Thus, the author concluded, although the Embedded Figures Test is considered basically a spatial task, usually associated with right hemispheric functioning, the kind of processing required by the task is more characteristic of analytical, left hemispheric processing.

This conclusion is consistent with the findings of Ornstein, Johnstone, Herron & Swencionis (1979). They concluded that the complexity of the task is a crucial factor, and that when the task becomes sufficiently complex, a verbal analytic strategy becomes significant regardless of whether the problem is verbal or nonverbal.

Intra-Hemispheric Differences, Cognitive Strategies and Dual Coding

As has been pointed out by Madden and Nebes (1980), hemispheric specialization of functions can be viewed as a complex phenomenon that is influenced by a number of variables such as type of stimuli, type of response required, and delay in response. Another possible interpretation of the above findings is that, for females, the Embedded Figures Test (which involves mental rotation) allowed verbal mediation to occur in the solution of the task, and they thus used a different kind of processing to solve the task than did males. Mental rotation (usually considered a spatial task) may be simply more verbal in females than males, and, as Freedman (1979) concluded, not necessarily less efficient.

The kind of processing required or allowed by a task may be the most important determinant in performance differences between males and females. This view is not inconsistent with a model of cerebral hemispheric functioning which ascribes differential lateralization patterns for males and females. Both of these are consistent with Paivio's model of dual coding.

Certain conclusions, regarding hemispheric functioning in general, can be drawn. As Paivio (1983) stated in a recent review of the literature on dual coding theory:

> Even allowing for the tentativeness of some of the facts, however, the neuropsychological observations are generally consistent with the dual coding idea of two separate cognitive systems that are specifically for dealing with different classes of information in a modality specific fashion. (p.323)

Purpose of Study

The purpose of this study is to use Paivio's model of dual coding to investigate sex differences in spatial and verbal learning. The Paivio model assumes three types of processing information: simultaneous processing of "spatial" or nonverbal material, sequential processing of "verbal" material, and dual processing, which involves both simultaneous and sequential processing of material which lends itself to both types of coding. Simultaneous processing is defined as the parallel organization and synthesis of unlike elements. Sequential processing is defined as analayzing information by abstracting out relevant details in a logical, step-by-step fashion (Paivio, 1971).

The proposed study represents an initial attempt to demonstrate that sex differences can be explained by the dual coding model. This study will attempt to show that sex differences in spatial and verbal abilities can be explained in terms of variations in the nature of the tasks and time allowed for information processing by males and females. Males are expected to perform better than females on tasks which require simultaneous processing of nonverbal or spatial materials. Females are expected to perform better than males on tasks which require sequential processing of verbal materials. It is contended that the female "disadvantage" on spatial tasks can be "overcome," providing these tasks and materials allow for dual coding of information. Females are hypothesized to perform better on tasks which allow for dual coding because they (unlike males) are assumed to lack lateralization of processing function.

In an initial study of dual coding, Paivio and Csapo (1969) investigated the availability of the three types of processing. Their stimuli varied on a dimension of content and concreteness: visually concrete (concrete pictures), verbally concrete (concrete words), or verbally abstract (abstract words). Paivio did not include stimuli which were visually or "spatially" abstract.

According to Paivio, another major variable which determined the type of processing hypothesized to occur was the rate at which stimuli were presented. Dual coding was hypothesized to occur only at the slow rate because spatial and verbal information involved two separate representational systems, according to Paivio (1971).

The proposed study will investigate the relationship of sex differences in spatial ability to dual coding. This will be accomplished by varying the abstractness/concreteness of stimuli and the rate of their presentation. Both verbal and visual stimuli will be used. The abstractness/concreteness dimension will be varied using visual stimuli only. According to Paivio, dual coding can occur with concrete but not abstract stimuli. Therefore, by manipulating the abstractness/concreteness of the stimuli, one can control the possibility of dual coding occurring. Paivio's study (Paivio and Csapo, 1969) was primarily concerned with the concreteness/abstractness of verbal stimuli. In the present study, the abstractness/concreteness dimension of spatial materials will be explored. Geometric forms will be added as task stimuli to look at possible differential performance on easily "nameable" and "nonnameable" geometric stimulus materials. Nonnameable geometric forms are hypothesized to be more abstract than nameable geometric forms. Nameable geometric forms are hypothesized to be similar to concrete pictures in their concreteness, and therefore both lend themselves to dual coding. All stimuli will be presented at both a fast rate and a slow rate.

Hypotheses

With regard to the present study, the following hypotheses have been formulated:

H_1: Females will have higher recall memory scores than males on a task requiring sequential processing of verbal material (abstract words), regardless of time permitted for encoding.

H_2: Males will have higher recognition memory scores than females on a task requiring simultaneous processing of spatial materials (nonnameable geometric forms), regardless of time permitted for encoding.

H_3: Males will display higher recognition memory scores than females on tasks allowing for sequential processing of spatial materials (concrete pictures, and nameable geometric forms) except when sufficient time is provided for dual coding to occur. When sufficient time is provided, male and female scores will be similar.

Method

Subjects

The sample consisted of 205 subjects, 99 males and 106 females. Subjects were undergraduates of New York Technical College, and ranged in ages from 17 to 30. Adolescence has been the accepted established minimal age for sex differences in both spatial and verbal abilities to be demonstrated, with consistent differences in spatial abilities appearing around 17 or 18 (Burstein, et al., 1980; Harris, 1978; Maccoby and Jacklin, 1974). College (undergraduate, technical college) students were used to help control for individual differences by providing a more homogeneous sample. No subject was currently enrolled in remedial classes.

Materials

Stimuli - Four types of stimuli were used:

1) abstract words (nouns)
2) concrete pictures
3) nameable geometric forms
4) nonnameable geometric forms

Ten items of each type of stimuli were presented (ten abstract words, ten concrete pictures, etc.) with a total of 40 stimulus items presented in all.

The items in each category type were as follows:

1) abstract words:
   1. ability
   2. abduction
   3. aptitude
   4. competence
   5. inclement

6. distinction
7. exhaustion
8. jealousy
9. quality
10. sensation

These items were chosen from Paivio, Yuille, and Madigan (1968) and were matched for frequency, word length and concreteness, as closely as possible. Concreteness scores ranged from 1.77 to 3.40 with the higher scores indicating a higher level of concreteness. Inversely, a lower score indicates a higher level of abstractness. No item had a concreteness score of over 3.40, resulting in all items being relatively high in abstractness.

2) <u>concrete pictures</u>:

1. lobster
2. girl
3. pencil
4. cigar
5. vest
6. butterfly
7. apple
8. boy
9. spoon
10. dog

These items were chosen from Paivio, Yuille, and Madigan (1968) and consisted of black and white line drawings of the above objects rendered by an artist.

3) <u>nameable geometric forms</u>:

1. triangle
2. an X

3. rectangle
4. hexagon
5. rhombus
6. asterisk
7. semicircle
8. oval
9. octagon
10. triangle inside circle

These forms were chosen from Piaget and Inhelder (1967) and were matched for level of complexity as closely as possible.

4) <u>nonnameable geometric forms</u>: See Appendix A.

These forms were chosen from the Primary Mental Abilities Test, Thurston (1962), and selected by an artist as "abstract" (five open forms, and five closed forms).

<u>Procedure</u>

Subjects were tested in small groups. There was a total of 22 groups.

Subjects were told that they would be shown several items which they would be asked to remember.

Subjects were presented with four blocks (one of each type) of stimulus items. Each block of stimulus items consisted of ten items of the same stimulus type (abstract words, concrete pictures, nameable geometric forms, nonnameable geometric forms). Items were presented one at a time by use of a carousel slide projector.

The four blocks were presented in random order. An <u>A</u> and <u>B</u> presentation order of items within each block was used to control for order effects and balanced for primacy and recency effects (see below). Groups were randomly assigned to the A and B order.

Within each block, five items were presented at the slow presentation rate (3.5 seconds between each item), followed by the final five items at a faster rate (.6 seconds between each item). Each item was presented for .23 seconds. The fast rate was achieved by placing a slide in each successive slot of the carousel slide tray. The slow rate was achieved by allowing three slots between slides. The rates of presentation used here were adjusted and are slightly faster than those used by Whitehouse (1981), whose subjects were brain damaged patients. Pilot testing determined that these rates resulted in appropriate error rates for the "normal" sample used. A and B presentation order at the slow and fast rates were as follows:

	Order A	Order B	
	1	3	
	2	4	slow or fast
fast or slow	3	9	
	4	2	
	5	7	
	5	1	
fast or slow	7	8	
	8	10	fast or slow
	9	5	
	10	6	

After each block was presented, a response (test) period immediately followed. Paivio's original design (Paivio and Csapo, 1969) required subjects to verbally name items as the response mode to the task performed. By requiring subjects to "name" items, either orally or in writing, he, in essence, unintentionally forced "dual" coding and therefore, confused his results to some extent. The same can be said of Ernest's (1983) picture identification task. It was our intention to avoid this pitfall, by not requiring "dual" coding by the nature of the task itself. Therefore, since all material was visually presented, and involved visuospatial materials (except for abstract words), a response which <u>did not</u> involve the verbal mode for those items was chosen. A response mode that is "visual" and nonverbal in nature was preferred, since it did not "mix" codes.

In addition, according to Paivio (1971), recognition memory tasks are the least complex of the tests of memory. Although some differences do exist between recall and recognition memory tasks, the relative effects of the different meaning attributes in free recall are strikingly similar to their effects in recognition memory. Concreteness has a positive effect on both recall and recognition memory. The present study varied stimulus concreteness. Paivio (1971) further hypothesized that for his dual coding study it was experimentally more important to distinguish between memory tasks that involved serial learning and those which did not (memory span tasks), and between short term and long term memory tasks. Free recall, according to Paivio, is most appropriate for verbal stimuli. Therefore, in the present study, for verbal stimuli (abstract words) a free recall task was employed, as in Paivio's original dual coding study (Paivio & Csapo, 1969).

The following test materials and procedures were designed to be used in this study for the recogniton memory task which was adapted from Whitehouse's version of Paivio's dual coding study (1981).

Test materials and procedures. Subjects were presented with a sheet of paper containing the original ten stimulus items plus an equal number of distractor items in each category (except for abstract words). Subjects were asked to select the correct 10 items by circling them on the page. Position of the items on the page were randomized in rows of four (five items per row). Pilot testing determined that distractors produced an appropriate error rate. Distractors were chosen according to the following criteria in each category:

1) *concrete pictures*: distractor pictures were chosen according to perceptual similarity to the original stimulus items (e.g., lobster--original stimulus item, and crab--distractor item). Items and distractors were as follows (See Appendix B):

Original stimulus	*Distractor item*
1) lobster	1) crab
2) spoon	2) shovel
3) apple	3) baseball
4) vest	4) dress
5) cigar	5) candycane
6) butterfly	6) bird
7) shovel	7) broom
8) boy	8) man
9) girl	9) woman
10) dog	10) cat

Because item difficulty on pilot testing did not yield a sufficiently high error rate with concrete pictures, Paivio's original stimuli were modified to include visual "background and noise" and pilot tested to assure a sufficiently high error rate.

2) nameable geometric forms. Distractors were chosen from Piaget and Inhelder (1967) and matched according to level of complexity and perceptual similarity to the original stimulus items. Distractor items were chosen to be similar in shape to the original stimulus items, but have another label (name), for example, rhombus--original stimulus item, square--distractor item. Items and distractors were as follows (See Appendix C):

Original stimulus	Distractor item
1) triangle	1) cone
2) an x	2) a cross
3) rectangle	3) trapezoid
4) hexagon	4) diamond
5) rhombus	5) square
6) asterisk	6) star
7) semicircle	7) quartermoon
8) oval	8) elipse
9) octagon	9) circle
10) triangle inside circle	10) circle inside triangle

3) nonnameable geometric forms. Distractor items for nonnameable geometric forms were taken from other choices in Primary Mental Abilities Test (Thurstone, 1962), which appear to be similar in perceptual attributes to the original stimulus items. (See Appendix A).

4) abstract words. Subjects were asked to write as many of the 10 words as they could remember, immediately following presentation

of the stimuli. This procedure replicated Paivio and Csapo's (1969) original dual coding study, and does not present the same difficulty with "mixing" codes as do the spatial stimuli.

Scoring. Subjects received one point for each correct stimulus item identified, yielding a possible score of 10 for each stimulus category, yielding a total range from 0 to 40.

Design

The effect of various stimuli and time permitted for encoding on male/female performance differences on spatial and verbal tasks were investigated using a series of 2 x 2 designs as follows:

1) Sex by Rate using Abstract Words

	slow	fast
female		
male		

2) Sex by Rate using Concrete Pictures

	slow	fast
female		
male		

3) Sex by Rate using Nameable Geometric Forms

	slow	fast
female		
male		

4) **Sex by Rate using Nonnameable Geometric Forms**

	slow	fast
female		
male		

It is possible to restate the hypotheses in the following symbolic form:*

H_1 : For design #1: $\underline{M}_F$: fast $>$ $\underline{M}_M$: fast ; $\underline{M}_F$: slow $>$ $\underline{M}_M$: slow

H_2 : For design #4: $\underline{M}_M$: fast $>$ $\underline{M}_F$: fast ; $\underline{M}_M$: slow $>$ $\underline{M}_F$: slow

H_3 : For designs #2 and 3:
$\underline{M}_M$: fast $\underline{M}_F$: fast ; $\underline{M}_M$: slow $\cong$ $\underline{M}_F$: slow

*** The following convention was adopted to represent the independent variables. The first variable represents sex (male/female). The second variable represents rate (fast/slow).**

Results

The data were analyzed in two separate phases. In the first phase, the hypotheses were tested directly using one-tailed *t* tests. During the second phase, summary analyses were conducted separately for each dependent measure. The effect of stimuli and encoding time (fast and slow rates) on male/female performance differences were measured using 2 (sex) x 2 (rate) analyses of variance for each type of stimulus (abstract words, nonnameable geometric forms, nameable geometric forms, concrete pictures).

Primary Analyses

Hypothesis 1 dealt with male/female differences in the processing of verbal material. Specifically, hypothesis 1 stated:

> Females will have higher scores than males on a task requiring sequential processing of verbal material (abstract words), at the fast rate and at the slow rate of presentation.

A comparison of male/female performance on a recall memory task at the fast and slow rate on abstract words revealed that females ($M = 1.73$) were significantly better than males ($M = 1.42$) when stimuli was presented at the fast rate, $t\ (203) = -1.42$, $p < .01$, but not at the slow rate of presentation, $t\ (203) = -1.34$, $p < .09$. At the slow rate of presentation, the mean score for female performance was 2.04, and the mean for male performance was 1.82. This statistical comparison for the slow rate of presentation did not achieve the conventional significance levels. There was, however, a directional tendency toward the predicted hypothesis. In addition, female's memory ($M = 3.76$) was significantly better than male's ($M = 3.24$) at the combined rate, $t\ (203) = -2.43$, $p < .008$. Therefore, hypothesis 1 was partially confirmed, indicating the superiority of female recall memory over male performance on verbal stimuli at the fast and the combined rate, but not at the slow rate. However, at the slow rate, the data approached significance in the predicted direction.

Hypothesis 2 provided a test of male/female differences in the processing of spatial material. Specifically, hypothesis 2 stated:

> Males will have higher recognition scores than females on tasks requiring simultaneous processing of spatial materials (nonnameable geometric forms), at the fast and at the slow rate of presentation.

A comparison of male (M = 3.0) versus female (M = 2.98) recognition memory for nonnameable geometric forms revealed no significant difference in performance at the fast presentation rate, t (203) = 0.12, p >.05. Nor was the difference between male (M = 3.57) and female (M = 3.54) recognition memory statistically significant at the slow rate, t (203) = 0.20, p >.05. Thus, this hypothesis was not supported. On nonnameable geometric forms, male recognition memory was not superior statistically to female performance at either presentation rate or at the combined rate.

Hypothesis 3 provided a test of male/female differences in the processing of materials which possibly lend themselves to dual coding. More specifically, hypothesis 3 stated:

> Males will display higher recognition scores memory than females on tasks allowing for sequential materials (concrete pictures and nameable geometric forms), at the fast rate of presentation. When sufficient time is provided for dual coding to occur (at the slow rate of presentation) male and female scores will be similar.

A comparison of male/female performance at the fast and slow presentation rates on nameable geometric forms revealed that male recognition memory (M = 3.63) was significantly better than female performance (M = 3.37) at the fast rate, t (203) = 1.74, p <.04. At the slow rate, male

(M = 4.00)/female (M = 3.90) recognition memory was comparable statistically, *t* (203) = 0.39, *p* >.05. This evidence confirms that part of hypothesis 3, involving nameable geometric forms as stimuli. Males did remember stimuli presented at the *fast* presentation better than females, but at the slow rate, male/female scores were similar. However, on concrete pictures, a comparison of male/female performance at the fast rate revealed that male recognition memory (M = 3.50) was not significantly better than female's (M = 3.57), *t* (203) = -0.47, *p* >.05. Interestingly, at the slow rate of presentation, female recognition memory (M = 4.07) was *significantly better* than male's (M = 3.82), *t* (203) = -1.74, *p* <.04. Although this difference was not specifically predicted, related evidence (presented below) provided support for the general hypothesis that male/female performance would be similar at the *fast* rate, but with female performance overcoming male performance at the slow rate (when dual coding could occur).

Summary Statistical Analyses

The mean and standard deviation for each cell in the statistical designs are presented in Table 1. As can be seen in Table 1, the absolute mean differences between male and female performance were small. Separate analyses were performed on each of the four dependent measures.

Table 1

Mean and Standard Deviation Scores for Male/Female Performance at the Fast, Slow and Combined Rate for Four Dependent Measures (Abstract Words, Nonnameable Geometric Forms, Nameable Geometric Forms, Concrete Pictures).

Dependent Measure	Summary Statistics n	M	S.D.
Abstract Words			
Fast			
Male	99	1.42	0.91
Female	106	1.73	1.10
Slow			
Male	99	1.82	1.21
Female	106	2.04	1.14
Combined			
Male	99	3.24	1.46
Female	106	3.76	1.60
Nonnameable Geometric Forms			
Fast			
Male	99	3.00	1.13
Female	106	2.98	1.11
Slow			
Male	99	3.57	1.05
Female	106	3.54	0.99

Table 1 (continued)

Dependent Measure	Summary Statistics n	M	S. D.
Nonnameable Geometric Forms (continued)			
Combined			
Male	99	6.57	1.53
Female	106	6.52	1.46
Nameable Geometric Forms			
Fast			
Male	99	3.63	1.07
Female	106	3.37	1.06
Slow			
Male	99	3.96	0.93
Female	106	3.91	1.03
Combined			
Male	99	7.56	1.49
Female	106	7.27	1.32
Concrete Pictures			
Fast			
Male	99	3.50	0.97
Female	106	3.57	1.16
Slow			
Male	99	3.82	1.09
Female	106	4.07	0.95

Table 1 (continued)

Dependent Measure	Summary Statistics		
	n	M	S. D.
Concrete Pictures (continued)			
Combined			
Male	99	7.31	1.56
Female	106	7.63	1.60

First, a 2 (sex) x 2 (rate) repeated measure analysis of variance was conducted with abstract words. Table 2 summarizes the results of that analysis and indicates a significant main effect for sex, with females' performance (M = 3.76) surpassing males' (M = 3.24) regardless of rate of presentation. There was also a significant main effect for rate of presentation, with the mean of the slow rate (1.93) exceeding that of the fast rate (1.57). The rate by sex interaction did not achieve statistical significance.

Table 2

Analysis of Variance for Sex and Rate on Abstract Word Scores.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Sex (Male/Female)	6.97	1	6.97	5.90*
Error	239.64	203	1.18	
Rate (Fast/Slow)	12.73	1	12.73	10.41**
Interaction	0.17	1	0.17	0.14
Error	248.18	203	1.22	

* p <.01

** p <.001

Second, a 2 (rate) x 2 (sex) repeated measure analysis of variance was performed on nameable geometric form scores. Table 3 which summarizes the results of those findings, revealed no significant main effect for sex (mean score for males was 7.59 and mean score for females was 7.27). However, a significant main effect for presentation rate was found, with the mean of students given stimuli at the slow rate (3.93) exceeding the mean of those given at the fast rate (3.50). The rate by sex interaction did not achieve statistical significance.

Table 3

Analysis of Variance for Sex and Rate on Nameable Geometric Form Scores.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Sex (Male/Female)	2.50	1	2.50	2.5
Error	201.54	203	0.99	
Rate (Fast/Slow)	19.42	1	19.42	17.6**
Interaction	1.07	1	1.07	0.9
Error	223.17	203	1.09	

** $p < .001$

Third, a 2 (sex) x 2 (rate) repeated measure analysis of variance was performed on nonnameable geometric form scores. Table 4 summarizes the results. The analysis similarly revealed no significant main effect for sex (mean score for males was 6.57 and mean score for females was 6.52). However, a significant main effect for rate was also found, with the mean of students given stimuli at the slow rate (3.55) exceeding the mean of those given at the fast rate (2.99). The rate by sex

The rate by sex interaction did not achieve statistical significance.

Table 4

Analysis of Variance for Sex and Rate on Nonnameable Geometric Form Scores.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Sex (Male/Female)	0.06	1	0.06	0.05
Error	226.39	203	1.11	
Rate (Fast/Slow)	32.23	1	32.23	27.24**
Interaction	0.00	1	0.00	0.00
Error	240.24	203	1.18	

** $p < .001$

Fourth, a 2 (sex) x 2 (rate) repeated measure analysis of variance was performed on concrete pictures scores. The results which are summarized in Table 5 indicated no significant main effect for sex (mean score for males was 7.31, mean score for females was 7.63). However, a significant main effect for rate was found, with the mean of the slow rate (3.94) exceeding the mean of the fast rate (3.03). The rate by sex interaction did not achieve statistical significance.

Table 5

Analysis of Variance for Sex and Rate on Concrete Pictures Scores.

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Sex (Male/Female)	2.60	1	2.60	2.08
Error	253.97	203	1.25	
Rate (Fast/Slow)	17.34	1	17.34	18.33**
Interaction	0.79	1	0.79	0.85
Error	192.07	203	0.94	

** $p < .001$

Discussion

Support for Hypotheses

The present study represents an initial attempt to explain sex differences in spatial abilities using a dual coding model. Several hypotheses were advanced regarding previously reported sex differences in terms of Paivio's dual coding model. Specifically, it was predicted that sex differences in spatial and verbal abilities could be explained in terms of variations in the nature of the task and time allowed for information processing by males and females. The present findings will be discussed according to the proposed hypotheses for each of the dependent variables.

Paivio's (1971) model assumes three types of processing of information: simultaneous processing of "spatial" or nonverbal material, sequential processing of "verbal" material, and dual processing of material which lends itself to both types of coding. Paivio's initial dual coding experiment (Paivio and Csapo, 1969) did not address the issue of sex differences in performance. Sequential and simultaneous processing strategies were assumed to be determined only by the type of stimulus material that was presented and by the presentation rate of these materials.

According to Paivio's dual coding model (Paivio and Csapo, 1969) abstract verbal stimuli (abstract words) can only be coded sequentially (linguistically), regardless of the time available. Hypothesis 1 predicted that female performance on a task involving the coding of verbal stimuli (abstract words) would be superior to male performance, regardless of time permitted for encoding (at both the fast and slow rates of presentation). The data provided support for hypothesis

1. As predicted, the analysis of variance performed on abstract words indicated female performance was significantly higher than male performance, regardless of rate of presentation. In addition, females performed better than males on abstract words at the fast rate and the combined rate. This finding supports hypothesis 1. However, although the sex differences in performance at the slow rate did not differ significantly, the data were in the predicted direction ($p < .09$). These findings thus provide some indication that sex differences in coding occurred based on the type of stimuli presented and the amount of time available. Female performance remained superior to male performance on abstract words at both rates of presentation, and the overall analysis did provide statistical support for the hypothesis, suggesting that female performance is superior to male performance when tasks are "purely" verbal in nature.

In Paivio's initial dual coding experiment (Paivio and Csapo, 1969), dual coding was theorized to occur when sufficient time was permitted for the encoding of material which could be processed in both modes. The concreteness of the stimuli was hypothesized to determine the possibility of dual coding. Paivio used concrete pictures as stimuli to test this prediction. Hypothesis 3 in the present study predicted that male performance would be superior to female performance on a dual coding task that is fundamentally "spatial" in nature, but could be verbally encoded (nameable geometric forms and concrete pictures), if coding time was restricted. However, sex differences in recognition memory could be eliminated by providing additional time for dual coding. The data provided some support for hypothesis 3. As predicted, when nameable geometric forms were used as stimuli a comparison of male and female performance at the *fast* rate revealed a significantly higher recognition memory by males. At the *slow* rate, however, no sex differences were found in recognition memory. This outcome supports hypothesis 3. Thus, the initial female disadvantage on a task seemingly "spatial" in nature seemed to diminish when additional time was permitted for females to encode the information in a "verbal" or sequential manner as well. Presentation rate, according to the dual coding model (Paivio, 1971), is important only when learners view stimuli which are appropriate for more than one type of processing to occur, i.e., stimuli that are concrete in nature.

While the data on concrete pictures as stimuli did not support hypothesis 3 as originally stated, related evidence offered some support for a more general hypothesis. Male performance was not found to be significantly better than female performance at the fast rate as predicted. However, at the slow rate, female performance *was* significantly *better* than male performance, suggesting that when dual coding could occur (with additional time), females were able to utilize dual coding and surpassed male performance on this task. This finding is in keeping with the notion that sex differences in recognition memory are found to vary based on the type of stimuli used and time restrictions. Such data provide support for the presence of sex differences in processing strategy (a dual coding explanation).

The results of learning other stimuli did not conform to prediction. Paivio's initial dual coding study (Paivio and Csapo, 1969) investigated concrete imagery and *verbal* coding. The present study attempted to extend his model by applying it to the study of *nonverbal* coding (simultaneous processing): i.e., the processing of abstract nonverbal or "purely spatial" information. Hypothesis 2 predicted that male performance on a task involving the coding of abstract spatial stimuli (nonnameable geometric forms) would be superior to female performance, regardless of time permitted for encoding to occur (at both the fast and slow rates of presentation). Hypothesis 2 was not supported by the data.

Conclusions

This study was a first effort to apply Paivio's dual coding model to the study of sex differences in imaginal relations and verbal coding. How well did this model work? The present evidence indicated that the dual coding model does seem to explain sex differences in the processing of verbal information or information which is available to verbal coding (concrete pictures and nameable geometric forms).

The data involving the coding of "purely verbal" material (abstract words), i.e., information which presumably could only be coded in the verbal sequential mode, produced the expected sex differences. Females were superior to males in the performance of this type of task, regardless of the rate of presentation. This finding lends support to the already existing body of literature (e.g., Harris, 1978; Maccoby and Jacklin, 1974; Oetzel, 1966) which indicates females are superior to males on tasks presumably verbal in nature. The dual coding model seems to have adequately described these sex difference.

The data involving the coding of information which could be dually coded (sequentially or simultaneously) also produced sex differences in the expected direction. This evidence involved "spatial" information which was also available to the "verbal" (sequential) mode of coding (concrete pictures and nameable forms). Since sex differences were found to vary based on both the type of stimuli and the time permitted for encoding to occur, the evidence suggests that sex differences could be attributed to differences in processing strategy. Although the results were not entirely supportive of the original hypothesis, the spirit and direction of the theory was supported. Thus, with nameable geometric forms, the initial female disadvantage on a task seemingly spatial in nature was diminished given task modifications which permitted females to encode this "spatial" information in a verbal or sequential mode. Females did not evince poorer performance on concrete pictures. However, with both nameable geometric forms and concrete pictures as stimuli, female performance improved compared to male performance when additional time was allowed for dual coding to occur. This suggests that when females are able to employ a verbal (sequential) mode of coding with spatial material, their performance improved in relation to male performance.

In the present study, performance on a task using nameable geometric forms was predicted to be parallel to performance on a task using concrete pictures because female performance (with both stimuli) was predicted to gain advantage when additional time was allowed for dual coding. The findings on concrete pictures and nameable geometric forms appeared to support this hypothesis. There was a significant improvement in female performance relative to that of males at the slow rate with both types of stimuli. Although as expected, male performance at the fast rate demonstrated a relative advantage over female performance on nameable geometric forms, unexpectedly no sex differences were found with concrete pictures at this presentation rate. An additional unexpected finding with concrete pictures as stimuli was that females performed significantly better than males at the slow rate. This outcome, nonetheless, coheres with Paivio's theory, because female performance improved on concrete pictures when given the opportunity to dually code the "spatial" information.

According to Paivio (1971) it is the concreteness of stimuli which determined their dual codability. Therefore, the "labelability" of both types of "spatial" stimuli made them suitable for dual processing. Another possible explanation for the findings is that one type of stimulus (concrete pictures) is more easily labelled than the other (nameable geometric forms), i.e., concrete pictures are more "concrete" in nature than nameable geometric forms.

The latter explanation finds support in a later study by Paivio and Ernest, (1971) which used verbal and nonverbal stimuli to investigate imagery ability and visual perception. Three types of stimuli were used: single capital letters (verbal stimuli), pictures of familiar objects, and geometric forms (nonverbal stimuli). Comparisons showed that the two types of stimuli (pictures and geometric forms) were similar in all respects, except for mean labeling latency. Pictures were significantly more quickly labeled than geometric forms.

In addition, Paivio (1971) presumed that even at the fast rate (in his dual coding model), the appropriate labels for pictures could be retrieved from concrete memory images after the stimulus series was presented. Thus, Paivio hypothesized that even if concrete stimuli such as pictures could not be verbally coded at the fast rate when presented, they could possibly be coded verbally during retrieval if the visual image could be retained. Presumably, therefore, the more "imagable" and concrete the stimuli, the more easily labeled.

It is possible that because concrete pictures are more easily "imaged" and "labeled," and therefore more concrete than nameable geometric forms, they were also more easily dually coded even at the fast rate of presentation. According to Paivio (1971) it is both concreteness of stimuli and time restrictions which determine whether or not dual coding can occur. It seems to follow, therefore, that the more concrete the stimulus, the more easily it can be coded dually. This could hypothetically have given males a greater advantage over females when nameable geometric forms were presented as stimuli at the fast rate (when they could only be easily coded in the simultaneous mode). At the slow rate, when more time was allowed and dual coding could easily occur for both types of stimuli (concrete pictures and nameable geometric forms) nameable geometric forms could also then be easily dually coded. This allowed females to "overcome" their disadvantage on a task using spatial material by dually coding the information. The evidence seems to support this possibility.

Although Paivio's dual coding model does seem adequate for describing the processing of information available to verbal encoding, the dual coding model seems to fall short with the processing of "purely spatial" information, i.e., information not available to a verbal (sequential) mode of coding.

The present study attempted to extend Paivio's dual coding model to the processing of "purely spatial" material, i.e., material which was assumed to be "spatially abstract" and therefore only available to the nonverbal or simultaneous coding mode. Since this material was assumed not to be available during verbal (sequential) coding, it was expected that male performance would retain an advantage over female performance on a task using this material. The evidence did not support this hypothesis. The dual coding model does not seem to adequately describe the processes underlying sex differences with purely spatial material.

The hypothesis that males would perform significantly better than females with "spatially abstract" stimuli (nonnameable geometric forms) was not confirmed. This finding is particularly surprising in view of literature on sex differences in which males have been found to have superior spatial abilities when compared to females (e.g., Harris, 1978; Maccoby and Jacklin, 1974; Oetzel, 1966). It is also surprising in view of the findings of the present study and the resultant sex differences yielded when nameable geometric forms were used as stimuli. The finding that with nameable geometric forms (essentially spatial information which could be dually coded) males exhibited superior performance over females (at the fast rate) is in keeping with the vast body of literature on sex differences. One would expect at least a similar finding for nonnameable geometric forms (hypothesized to be "purely spatial" in nature).

These findings may indicate a shortcoming of Paivio's theory (1971). It is possible that the dual coding model adequately describes the processes underlying verbal functioning but does not adequately describe the processes underlying purely nonverbal functioning (simultaneous processing). Furthermore, the model may be best suited for describing the processing of either verbal materials or materials which lend themselves to dual coding (a verbal mode of coding <u>and</u> a nonverbal coding mode), but is not suited for explaining "purely" nonverbal or simultaneous functioning. This interpretation is supported by the fact that Paivio did not use the same experimental procedures to study the processing of spatial materials (Paivio and Ernest, 1971). Indeed, Carole Ernest (1983), who continued with this work, developed different procedures for assessing nonverbal functioning. She hypothesized that more factors needed to be taken into account when studying the processing of "spatial" material. Although placing her research within the framework of Paivio's dual coding approach to memory and cognition, Ernest (1983) distinguished the imagery system from the verbal system as one specialized for processing "concrete-perceptual" information such as nonverbal objects or events.

In her study of sex differences in spatial imagery ability, she felt it necessary to discuss these differences in terms of the neuropsychological literature on lateralization of brain function because Paivio's two symbolic systems seemed to have their counterparts in that body of literature. Ernest (1983) developed a hemispheric functioning model which describes male/female differences in terms of individual differences as well. She concluded that:

> ...individual differences in spatial imagery ability must be examined within the context of sex differences. Male and female high spatials do not always behave similarly, nor do male and female low spatials. Instead the sexes within these two ability groups appear to differ in an unexpected fashion in the 'lateralization of their _verbal_ functions' (pg.2).

What Ernest (1983) found in carrying out her studies involving sex differences in spatial imagery ability was that it was not enough to describe between group differences (male and female), one had to look at within group differences as well (high and low spatials). However, an even more unexpected finding for Ernest was that in addition to within group differences, strategies other than those associated with one's spatial ability could possibly account for the results of her studies. Those other factors involved verbal functioning. Thus the processing of "spatial" information seemed quite complicated. It seemed to be involved with and interdependent upon verbal functioning. This was <u>in addition</u> to other factors which involve the perception and processing of "purely" spatial information (information unavailable to a verbal coding mode and devoid of verbal elements), and perhaps more complicated processes as well. While Paivio's dual coding model is sufficient to adequately describe the former (verbal functioning), it falls short of adequacy for the latter (nonverbal).

In subsequent research Ernest (1983) decided it was necessary to consider within sex groups differences in spatial imagery, i.e., "low spatial" imagery performers, and "high spatial" imagery performers. Although she did not speculate concerning the "cause" of within group differences in spatial imagery, she cautioned:

> Individual differences must be considered because all individuals do not approach the same task in the same way. Secondly, a relationship exists between ability and strategy. That is, the effectiveness of a given strategy depends on one's pattern of abilities (Ernest, 1983, pg.8).

Ernest (1983) stated that imagery and perception tap similar underlying processes. This may have particular consequences for the coding of "purely spatial" information, which can only be processed in the nonverbal coding mode (simultaneous processing), which has no "verbal" elements at all, and is therefore unavailable to the verbal or sequential processing mode.

Ernest's (1983) findings and interpretation in terms of "brain lateralization" lend further support to and provide some explanation for present data on nameable geometric form stimuli (hypothesis 3).

Ernest's model links imagery ability to sex differences in the cerebral lateralization of verbal functioning (with female high spatials' verbal abilities located in both hemispheres). Hypothesis 3 predicted that females can "overcome" their disadvantage in processing some spatial information if sufficient time is permitted for dual coding to occur (which involves both the nonverbal and verbal mode of processing information). It is possible that females who perform well on imagery ability tasks are essentially encoding "spatial" information in a verbal or sequential manner. The availability of language functioning in both hemispheres may make this easier, since it was previously believed that the two types of processing were lateralized in different hemispheres (sequential processing in the left, and simultaneous processing in the right).

In sum, dual coding seems to provide an adequate model for explaining sex differences in the processing of "purely verbal" information. It also seems adequate for explaining sex differences in spatial abilities as long as verbal processing can occur. When stimuli does not permit verbal (sequential) encoding, the dual coding model seems insufficient to explain sex differences in the processing. In the present study, the dual coding model was unable to explain the processing of "purely" spatial information. Such other factors must be taken into consideration, as individual differences and their concomitant hemispheric functioning counterparts.

Recommendations for Future Research

Since this study represents an initial attempt at using the dual coding model to explain sex differences in spatial and verbal abilities, it opens many questions for inquiry by future research. Although the model appears to have promise, there are some significant shortcomings that must be addressed in future research. Although most of the evidence on "purely" verbal material (abstract words) supported the original hypothesis, some of the evidence at the slow rate only approached significance ($p < .09$). It is possible that with future research, more reliable results could be achieved by using a larger sample of subjects.

One reason offered for the differential results of using concrete pictures and nameable geometric forms (both dually codable) as stimuli was the relative concreteness of the stimuli. It is possible that the pictures were more concrete, and therefore more easily dually coded than nameable geometric forms, even at the fast rate, but both were equally amenable to dual coding at the slow rate.

It is also recommended that future studies use the dual coding model to focus further upon the relationship of "concreteness" of stimuli to sex differences found on "spatial" tasks which are dually codable. Since the present study yielded various results using nameable geometric forms and concrete pictures as stimuli, it is recommended that future studies investigate this question by selecting pictures that vary in concreteness as established during a pilot study. Perhaps the pilot study could have subjects rate the stimuli on the dimension of concreteness. This would enable a direct test of this hypothesis.

It should be noted that Paivio's research methodology did not _directly_ assess the use of coding strategies. Instead he relied on external manipulations that were theorized to affect verbal and imaginal coding. In future research, it might be desirable to directly measure the type of coding in operation. One method would be through the use of a questionnaire which asks the subject to describe the strategy or processing used. Another method of tapping the process itself would be to use pretest data in the two ability areas (spatial and verbal) as Carole Ernest (1983) did with high and low spatial ability. This might provide some concrete evidence as to the process itself, since as Ernest (1983) assumed, a relationship exists between ability and strategy.

Finally, it is recommended that while the dual coding model did not seem an appropriate model for explaining sex differences on tasks hypothesized to be "purely spatial" in nature, it may prove useful in combination with other factors. It may be necessary to use a paradigm which is informed by cerebral hemispheric considerations, since the two types of coding seem to have their counterparts in cerebral hemispheric functioning literature. This is the model advocated by Carole Ernest (1983).

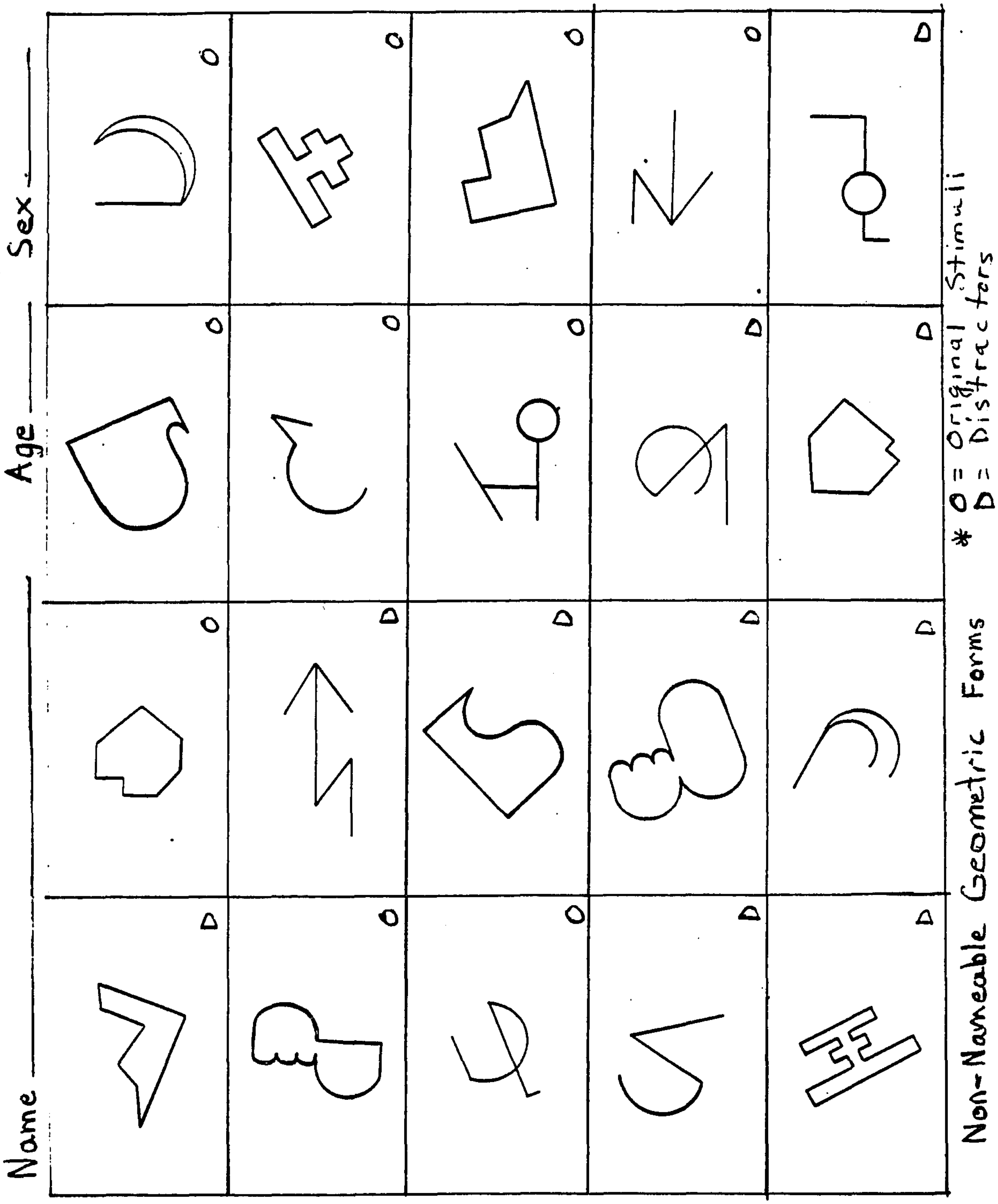
Educational Implications

By applying a dual coding model to sex differences in spatial and verbal abilities, a better operational definition of the cognitive strategies that underlie these abilities is made available. The conditions under which these cognitive strategies and their underlying processes occur is also made available, thus making it possible for educational interventions to occur. These interventions might seek to eliminate or manipulate sex differences. In other words, by redefining sex differences in terms of Paivio's dual coding model, one can change a seemingly "spatial" task by varying the task conditions, into a "verbal" task, and in that way "eliminate" the female disadvantage on such tasks.

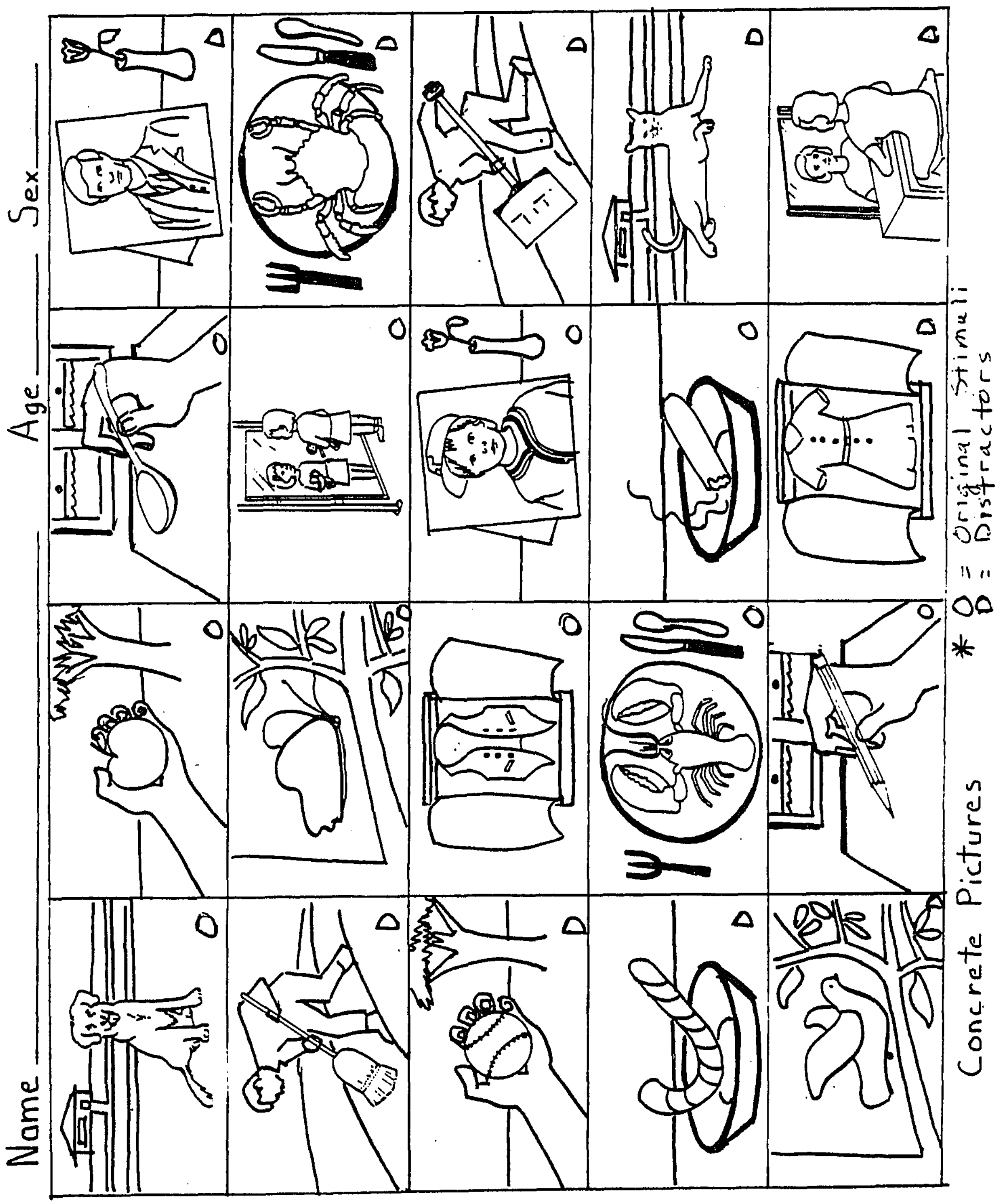
One can also vary the students' use of cognitive processes by means of training study interventions. A specific route for the possible educational utility of the findings of this study in "overcoming" sex differences in spatial abilities is to apply them to what is commonly know as "math anxiety in women." The present study lends support to the notion that it may not be the subject matter itself that is pedagogically difficult for females, but instead the manner in which the subject matter is conceptualized and presented. Spatial and nonverbal skills are an integral part of what is included in mathematic curricula in schools. Females could be taught to reinterpret spatial or mathematical problems in a verbal manner, thereby using a different problem solving strategy: one which is more suited to their processing preferences. By using a verbal mode to teach or explain spatial skills, it would be possible to enable females to overcome their math anxiety. Computers may be one method of integrating the visual with the verbal in order to accomplish this and in this way utilize a verbal mode to conceptualize a spatial or visual task.

Furthermore, if spatial ability proves to be important in higher education, and certain male dominated adult occupations, these skills could be "remediated" in the manner described above: i.e., by changing the task, or by changing the process. More specifically, course work in the male dominated fields such as architecture, engineering, and mechanics could be made more accessible to females by restructuring the information and concepts in the curricula. One possible way of accomplishing this would be to employ female instructors in these courses on a wider scale. These female instructors would presumably reencode the material to be learned in a manner more congruent with the female students' processing strategy (more verbally). Having been reinterpreted, the information and course work would be more easily integrated and learned by female students. Females could then become more proficient in the area of study, and eventually, the occupations that might have been otherwise unavailable to them.

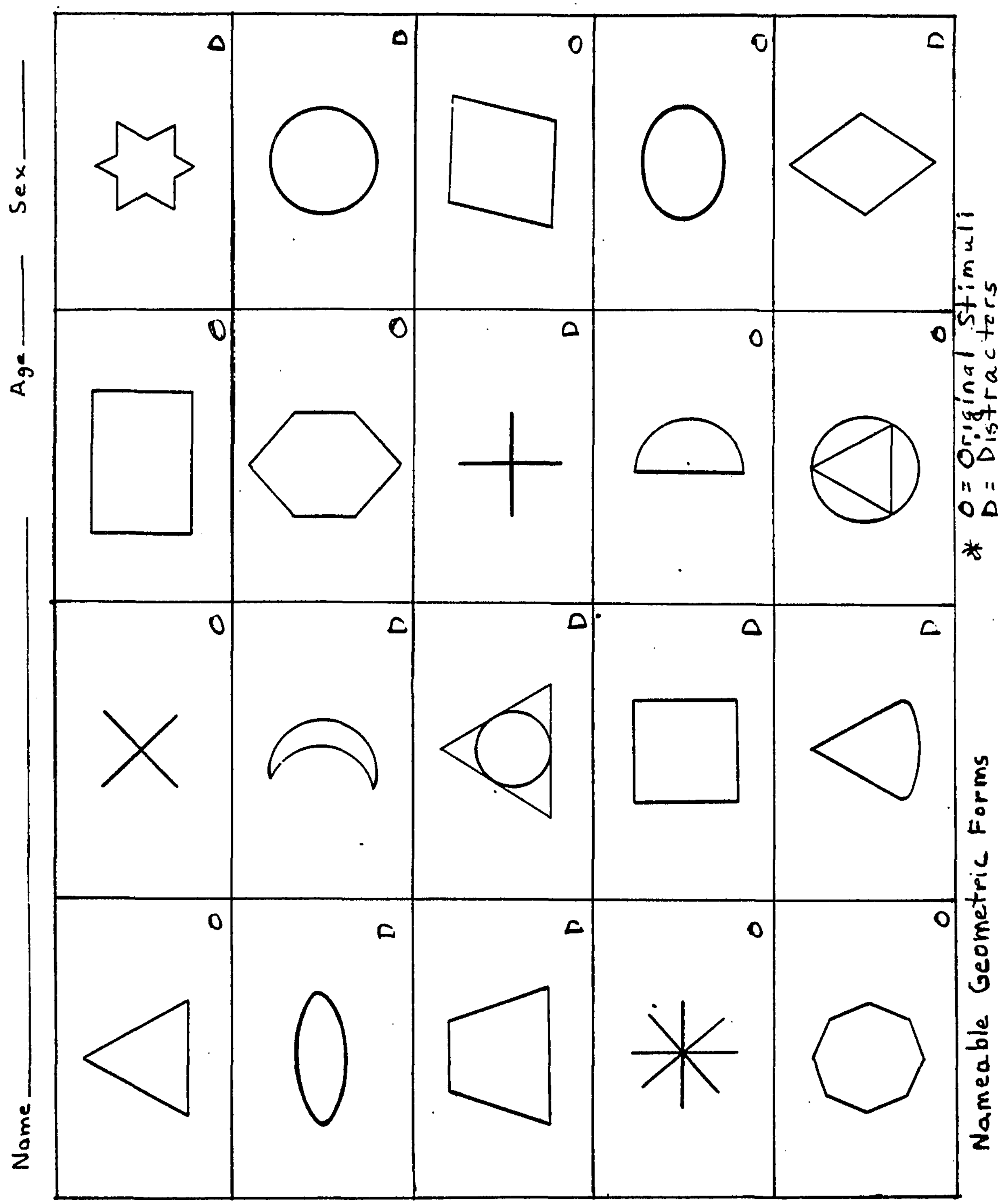
Appendix A


Name
Age
Sex
Non-Nameable Geometric Forms
* O = Original Stimuli
D = Distractors

Appendix B


Name
Age
Sex
Concrete Pictures
* O = Original Stimuli
D = Distractors

Appendix C


Name
Age
Sex
Nameable Geometric Forms
* O = Original Stimuli
D = Distractors

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