MENTAL OPERATIONS IN THE SPATIAL COGNITION OF THE ENVIRONMENT

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MENTAL OPERATIONS IN THE SPATIAL

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PREFACE

The topic of spatial cognition has many potential connections with problems in contemporary society. Just ask those around you how and with what degree of difficulty they determine directions or visualize a scene. You will discover that there are similarities and differences among the reports you receive, but always that the reports are emotionally tinged with degrees of pride or embarrassment.

I hope and feel that the research contained herein will serve to illuminate the processes involved in spatial cognition. The following people were instrumental in allowing me to take part in what has been a joy and a curse: My parents, who provided support of every imaginable kind; my adviser, Dr. Bob Weber, who exhibited infinite patience with my bumbling ways; my committee members, Dr. Bob Stanners and Dr. Larry Brown, who provided sound editing and valuable insight into my written efforts; Clyde Wolford, who spent infinite hours in constructing successive laboratories and in arguing with me the finer points of spatial cognition; and, last but not least, [redacted] me a better way.

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CHAPTER I

LITERATURE REVIEW

Introduction

How do people know where they are and where things are around them? The implication from a psychological point of view is that they form a mental representation of the environment that is available for consultation.

The study of mental maps has had a long and discontinuous history. At the turn of this century, a few scientists were concerned with how people know in which direction distant cities and countries lay. With the advent of modern quantitative methods, spatial cognition was studied in the laboratory through the administration of paper and pencil tests.

Since the cognitive revolution in modern psychology, there has been a plethora of research demonstrating the scope and speed of non-verbal thought processes. But it has been only within the past five years that comprehensive theories of spatial cognition have been advanced. Each of these topics will be reviewed in this thesis, in preparation for the presentation of a study designed to represent a modern methodology for the investigation of the spatial cognition of the environment.

Geographical Orientation --
Research Findings

Prior to World War I the majority of experimental investigations of human spatial cognition were concerned with describing the psychological processes underlying geographical orientation. Trowbridge (1913) asked subjects to mark on a circular sheet of paper the directions and distances of various near and far locations with respect to their own position. He found that the majority of his subjects exhibited marked misconceptions concerning the locations of international cities, and many of these subjects appeared to have rotated an imaginary map of the world, producing constant errors in all direction estimates but correct conceptions of the distances to and between cities. The errors of other subjects did not appear to be so regular, but instead seemed to depend upon the subject's familiarity with the area of testing, or even the direction in which he faced at the time of testing.

Trowbridge (1913) argued from such results for the existence of two "radically different" styles of orienteering. The first group seemed to be alone in determining directions by consulting mental maps which, in conjunction with the adoption of an abstract reference system such as knowledge of compass directions, allows a powerful way of navigating through unknown territory. However, such a method of orientation also has disadvantages in that improper assignment of cardinal directions to the map will result in its rotation and subsequently gross disorientation. The second group did not possess the mental map and instead, determined local directions by directly associating known landmarks to distant points. As long as the location of the landmark is known, orientation was maintained. The mechanism of orientation is obscure but probably involves the recollection of the motor movements necessary to face a given point in the home territory (Gregg, 1939). Obviously, such a system is useless in an unknown area. Thus, those subjects in Trowbridge's experiment who exhibited more random error probably were used to orientating themselves with respect to familiar landmarks which did not exist in the testing area.

Trowbridge termed the method of orientation that used an abstract reference system as being egocentric and the method using concrete landmarks as domicentric, although as Howard and Templeton (1966) point out, the term geocentric is preferred to egocentric. Later, researchers (Angyal, 1930; Claparede, 1924) confirmed the fact that there seem to be two styles of orientation, although they did not adopt Trowbridge's characterization of one's being civilized and one not. Specifically, they found both that some subjects determined directions without referring to the orientation of their physical body and that some did. The former correspond to those subjects in Trowbridge's study who consulted imaginary maps while the latter presumably did not access such an aerial-view type map, but instead may have imagined their environment as seen from ground level -- a much more "egocentric" (Trowbridge's domicentric) perspective. These subjects then would probably be less prone to make errors concerning near locations (assuming they were cognizant of their whereabouts), but more so with distant locations due to a lack of a large-scale cognitive map.

This distinction between styles of orienteering was approached by Ryan and Ryan (1940) from a phenomenological viewpoint. They asked subjects to verbalize processes as they determined directions of cities and found evidence for at least three kinds of orientation. First, subjects could visualize the scene beyond the obstruction of the laboratory wall as if the wall were removed. As the authors note:

> One of the simplest and commonest, and at the same time one of the most difficult to understand from the point of view of ordinary accounts of psychological activity is what we shall call 'primary directionalization.' Here the relation of the 'here and now' to other places is inherent in the present apprehended scene (p. 207).

Second, subjects could deduce directions by assigning verbal labels to landmarks. Here primary directionalization accounted for the accessing of the location of landmarks but compass directions were determined from the names associated with the landmarks (i.e., west hill). The third type of orientation involved the subject's seemingly scanning an imaginary aerial map of the surrounding area.

Geographical Orientation -- Conclusions

This research indicates the existence both of general processes and wide individual differences involved in the act of geographical orientation. People seem to determine directions of distant points on the earth by generating one or more of the following mental products. First, they can directly associate landmarks with unseen locations. Orientation is determined through recalling motor actions necessary to physically face the scene. Subjective experience probably involves a high degree of nonvisualization of the desired scene. Second, one can consult an imaginary map that contains the orientation and location of points in a symbolic, although quasi-spatial, framework. After the person determines his own orientation via referring to landmarks, he can determine the location of points by simply scanning the map. Some subjects may prefer to rotate the map so that its "north" corresponds to true geographic north. Finally, people may prefer neither to visualize nor scan a mental map, but simply to determine directions either by recalling propositional statements or associations about the relation of seen landmarks with unseen points.

Psychometric Research on Human Intelligence

Following the Second World War, factor analytic research methodologies enabled a more precise view of the processes underlying the introspections of the Ryan and Ryan (1940) subjects. Pioneers in the field had already established that spatial abilities were at least as important to general intelligence as verbal and performance abilities (Spearman, 1927; Thorndike, 1921; Thurstone, 1938), but the factor was diffuse and the tests for it appeared dissimilar. Gradually, evidence for two, and sometimes three, sub-factors appeared (Fruchter, 1954). The sub-factor most commonly agreed upon, spatial visualization, referred to the ability to imagine or project the positions of a group of objects after having undergone a prescribed rearrangement. An example would be to visualize the movements of the internal parts of a machine. A test loading high on this sub-factor, Punched Holls (1962), required the subject to decide if the holes in a flat sheet of paper would line up after the paper was folded along certain axes. In Figure 1, the correct answer is (d).

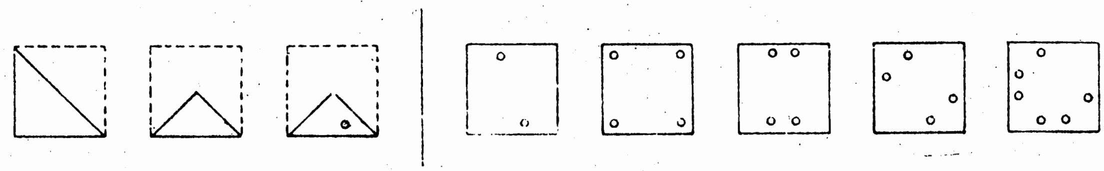
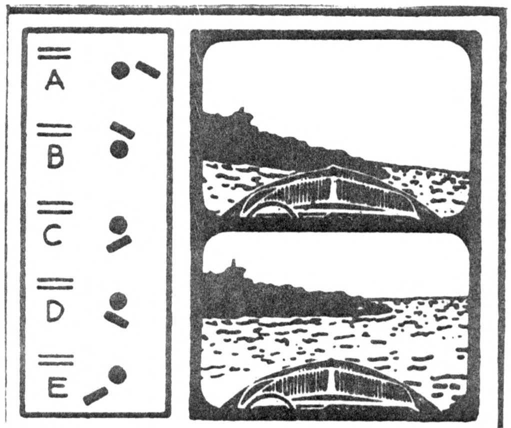


Figure 1. Test Item From Punched Holes Test

The second factor, spatial orientation (sometimes called spatial orientation-relations to include a third and indistinct sub-factor), emphasized the general ability to determine the arrangement of an object or group of objects with respect to one's own bodily position. In this case, the object array would undergo no more complicated a transformation than a change in appearance as if it were being viewed from another perspective. A test of this is Spatial (Ships) Orientation (1947), where two pictures, each containing the prow of a boat and a shoreline in the distance, are presented side by side. The subjects' task in this case is to decide which direction the boat has turned from the first to the second scene by selecting the change in background. In Figure 2, if the background is represented by the circle and the boat by the rectangle, the corect answer is D.

Although there is general agreement on the validity of two abilities or factors involved in spatial cognition, there is some argument as to exact definitions of them, or even whether they both should be considered spatial factors at all (as opposed to more general abilities). Michael, Zimmerman, and Guilford (1950, p. 190), hypothesized that the spatial visualization factor tapped the ability to mentally



Scene #1

Scene #2

Figure 2. Example of Ship's Orientation Task

manipulate objects within an array, while spatial orientation had to do with the ability to "comprehend the arrangement of elements within a stimulus pattern, previously with reference to the human body." They note that this ability would allow one to note whether one object array was or was not the same--but rotated--version of another array. In other words, an implication of this ability is to be able to visualize a scene as if one had changed position in space or if it had rotated. Michael et al. further postulated that whether one or the other ability was used, depended upon task complexity and the predisposition of the subject. Complex tasks requiring successive manipulation of an array, obviously would require the visualization factor as defined. On the other hand, if the tasks were simple enough to solve by noting if an array had undergone rotation, then spatial orientation would be adequate. However, some subjects might solve the rotation by manipulating a representation of it in successive increments, an indication of spatial visualization. Likewise, some subjects might solve a complex task by projecting themselves into the mental or visual representation (i.e., imagine that they are folding a piece of paper to see if the holes match). Although not iron-clad, the crucial distinction between the two operations seem to be whether the object array is represented as if it were seen in real life from a close or far visual point of reference. A crucial factor in which perspective is adopted is the nature of the object array represented as well as the complexity of the transformation, not to mention the subject's habitual means of solving spatial tasks and his general intelligence.

The complexity in this view of the differences between the two spatial factors led Smith (1964) to treat spatial visualization as the sole spatial ability, while spatial orientation arose from nonspatial sources. In this view, visualization is defined as the general ability to "retain and recognize (or reproduce) a configuration as an organized whole" (p. 62). The orientation factor gives rise to the ability to manipulate that representation. The obvious difference between this view and the previous one is the shift in assigning manipulative properties from the visualization to orientation factors. This view is generally upheld by Cattell (1971) and Pawlik (1966).

Until such time as there is some agreement on the nature of the abilities associated with the two spatial factors, research on the subject of spatial cognition is likely to be a thorny and confusing subject. Two recent articles on the genetics of spatial cognition should serve to illustrate the problem. Vandenburg (1969, p. 389) administered several tests of spatial abilities to pairs of twins, and concluded that ". . . it would seem that the perception of form and of perspective show a higher and more consistent tendency to have a significant hereditary component than do tests which require the ability to move objects around in one's mind."

Here, based upon the definitions of the two spatial factors, it seems that it is spatial orientation that seems to demonstrate an inherited component, only because of the emphasis upon knowledge of perspectives, which requires a knowledge of egocentive position. Yet, in his article summary, Vandenburg rephrases his conclusions:

> The results from this study suggest that it is mainly form perception, or the ability to keep a pattern or drawing in mind, as much as mental rotation required in some spatial visualization tests, which is determined, in part, by heredity (p. 293).

Here, again, based upon the two-factor distinction, it appears as if visualization and not orientation is genetically determined. Mental rotation of objects is a manipulative process removed from consideration of the person's egocenter (to some degree) and could be indicative of visualization as much as orientation. In the second study in question, Yen (1975) first reclassified the findings of Vandenburg and others in terms of visualization and orientation, and concluded that it is orientation that exhibits a genetic influence. Yen then administered four tests that supposedly measured 2- and 3-D visualization and orientation to a male-female population in an attempt to discover sex-linked genetic influences upon spatial ability. To measure 3-D orientation, Yen chose Vandenberg's (1973) paper and pencil version of the Shepard-Metzler (1971) task of mental rotation of 3-D objects. She found no evidence for a sex-linked influence, which, based on the previous analysis of mental rotation, is not surprising, for the task is not a measure of spatial orientation as defined by the research of Michael and his associates.

This type of research will obviously not advance until the components of spatial cognition are more clearly demonstrated. Although there is general agreement that there are at least two distinct operations occurring in these tasks, there is some agreement that the visualization operation is closely related to general intelligence. There is no agreement upon the nature of the second operation. Some suggest that it has to do with cognitive style, some with general manipulative facility. Others (Hart and Moore, 1973) suggest that it has to do with the developmental ability to coordinate perspective. At this point, the most reasonable research strategy might be to cease attempting to explain the nature of the factor, and instead, isolate some more of its parameters, such as who uses it, under what conditions, and is it necessary for all spatial tasks. The experiment advanced in this thesis is, in fact, an attempt toward that aim.

Psychometric Research - Conclusions

Two abilities have been found to be associated with spatial cognition. One, spatial visualization, refers to the ability to generate, and perhaps maintain, an imaginal representation of an object array. It seems most appropriate whenever the object array consists of a group of objects which must undergo a series of transformations. The second, commonly known as spatial orientation, underlies the ability to generate a view of an object array from a different perspective. The object array here usually undergoes the simple transformation of rotation in space. The distinction between the two factors is not clear-cut. Many spatial tasks require both of them to some degree, and therefore, they may or may not ever act in an additive fashion depending upon the nature of the task. The experiment described in this thesis should demonstrate some of those effects and interactions.

The study of spatial cognition to this point has moved from the field to the laboratory with some consistent findings. In solving spatial tasks, most people seem to rely heavily upon the generation and manipulation of imaginal representations of external objects. People seem to differ as to whether or not the self is inherent in that representation, and that fact has consequences upon the manner and speed in which the tasks are solved. They also differ in their use of verbal formula in solving the tasks. Thus, the study of spatial cognition should consider both aptitude and individual differences in subjects in order to attain some degree of comprehensiveness.

Contemporary Research

With the coming of modern cognitive psychology, reaction time methodologies, and the likening of human thought to the functioning of computers, came yet another perspective on spatial cognition. Roger Shepard and his colleagues at Stanford, in a series of elegant experiments, provided dramatic evidence that the transformation of mental representations of external objects occurs in a continuous fashion--suggesting, to them at least, that ". . . all thinking by humans, and other animals, is basically analogical" (Metzler and Shepard, 1974, p. 226). The importance of their research to this discussion lies more with the notion that the reaction-time methodology employed provides a springboard from which the operations involved in spatial cognition can be defined with greater precision.

In one study, Shepard and Feng (1972) found that the time which subjects took to determine what a flat piece of paper would look like after it was folded in a certain prescribed manner linearally increased with number of folds. One is immediately struck by the similarity between this task and the test of Punched Holes described earlier. The authors used this finding to argue for analogical processes. It also serves to show that visualization can be studied with a reaction-time technique.

Shepard's work is more often associated with his demonostration of mental rotation (Shepard and Metzler, 1971). Here, subjects first viewed a picture of an abstract 3-D object, followed by a second picture of either the same object from a different perspective or its mirror image. Reaction time to decide whether or not the first and second pictures depicted the same object was found to be near perfect linear function of the degree of angular difference between them. As discussed earlier, the task of mental rotation of a fixed object array seems to require the enactment of both of the operations of spatial orientation and visualization.

What seems to be missing is a demonstration of the operation of orientation alone.

What would such an experiment be like? First of all, the object array should be large, probably simulating the natural environment to aid the imagination of those who would treat the task as an abstract one. A scene resembling that in the test of Ships Orientation comes to mind. Using the Shepard paradigm, the obvious task would be to present the two pictures depicting a boat's prow and changing shoreline in succession. The time to decide should increase with the degree in which the boat is suggested to "turn." The interpretation of such results would resemble the general line taken by Shepard; that is, of a mental rotation. But in this case, just exactly what is rotated is not exactly clear. Is it the entire object array or is it one's own imagined body? The idea of rotation of the body seems more plausible in that it would probably require less cognitive effort (an effect of a qualitatively different kind discussed earlier). Rock (1973) in his discussion of the effects of orientation on form perception and the apparent paradox of retinal and environmental rotation would appear to agree:

> I would suggest that visualizing a figure in a different orientation from the one it is in occurs literally by rotating the figure in one's imagination by degrees until it has arrived at the desired orientation, or by visualizing the transformations the figure would undergo in its egocentric appearance as one turns by degrees until one arrives at the desired orientation. [Of the two visualizing the self turning seems easier and more natural to me] (p. 72).

The basic idea could be extended to most any environment by photographing it in successive increments about a central axis, resembling what one would see if one were to slowly turn around.

Such a study entails a few difficulties. A nice linear reaction time through 180 degrees of angular departure is improbable due to the fact that people can determine what is behind them and to the side as fast or faster than what is in front of them (personal communication, Clyde Wolford). The reason probably has to do with the natural asymmetry of the body and its influence upon the organization of cognitive space. The implication, rather, is that evidence for such mental rotation would have to be gathered in a more indirect fashion. Hochberg and Gellman (1977) have recently approached this subject although in an abstract fashion. They presented subjects with 2-D figures, asking them if they were rotated versions of previously presented figures or different figures entirely. Some of the figures contained information about orientation that was easily discernible while the same information in other figures took more searching to extract. Linear functions between angle departure of the first and second figures and reaction time such as Shepard obtained were suggested only for the data for the figures with disguised cues to orientation. The implication is that a holistic mental rotation seems necessary when a sequential mental comparison of features is ruled out or is cumbersome. (This mental rotation of an object would seem to possess components of both orientation and visualization, not being a clear example of either one as defined by Michael et al. [1957]). These findings suggest that in our hypothetical study concerning mental rotation and real-life environments, what Hochberg and Gellman (after Lynch, 1960) call landmarks may have an important effect on mental operations in spatial cognition. By providing cues to orientation, they may obviate the necessity to determine orientation solely by a holistic mental rotation of the imagined body, and instead, facilitate the scanning of a mental representation map.

As it will be recalled from Ryan and Ryan's work on geographical orientation, the locations of points is determined through a variety of means, including visualization of scenes, verbal formula, and the scanning of a cognitive map. Both factor-analytic and modern cognitive research has illustrated some of the parameters of visualization and its attendant operation of spatial orientation. Recent research also exists that sheds some light upon the operation of mental scanning of visual representations. Kosselyn (1973, 1974) asked subjects to focus their attention upon a certain feature of an imagined object (the headlight of a car) and then asked them to verify the existence of another feature that had a high probability of belonging to that representation (a door handle). The time which subjects took to decide whether their representation contained the appropriate feature increased as a linear function of the distance between the corresponding features of a typical "real" car. Apparently, subjects were scanning an internal representation much as one would visually scan a physical object. As did Shepard, Kosselyn used such research to argue for the existence of continuous mental operations utilizing more or less holistic mental representations, i.e., an analog view of cognition.

Conclusions and Directions for Future Research

Research on spatial cognition of the environment and factor analytic research on spatial cognition of idealized objects both pointed to the existence of at least two major factors; what we refer to here as spatial visualization and orientation. The visualization factor has been convincingly demonstrated by the work of Shepard and his associates, while the orientation factor has been neglected. An indication that this gap in knowledge may soon be rectified is forthcoming from such theories as Neisser (1976), who has called for such research to resume using object arrays that resemble the environment rather than the ideal objects used in the laboratory.

Kosselyn (1974) has provided a study that seems representative of the type of research that is needed. Working with a developmental framework, he gave children and adults practice in placing objects at pre-designated points on the floor of a life-sized experimental space, across which were hung either transparent or opaque sheets. It was found that subsequent estimations of the distances between pairs of objects from memory increased as a result of the intervention of both types of barriers for children (ages 4-5), while only the opaque barriers had such an effect for adults. The conclusion was that the children's representations of the experimental space were forced to become "compartmentalized" due to the barriers, and the same was true for adults, but to a lesser degree. That the opaque barrier effect was due to a deficiency in visualization capacity is suggested by the fact that being able to see through the transparent barriers allowed normal estimations for adults. However, the methodology does not allow one to consider the possibility that the effect might have been due to a lack of ability to represent views of a perspective different than the one in view. In other words, the two operations inherent in spatial cognition were not adequately partitioned to account for respective main and interaction effects between the twin spatial factors of visualization and orientation. The methodology contained in this research is an attempt toward the separation of those two factors in spatial cognition.

Individual Differences in Spatial Cognition

To complete this discussion on research, some mention should be given to recent indications of the great individual differences operating in spatial cognition.

With regard to the Shepard task and mental rotation in general, Hock and Ross (1975) have discovered that the time to mentally rotate a dot pattern was decreased by pre-exposing the patterns to the subjects.

However, the effect only existed for those subjects who could quickly discern if a pattern was symmetrical or not. Hock and Ross argued that these "structural" subjects, as opposed to the other "analytic" subjects, typically process information in a more holistic manner. The fact that there seems to be such striking individual differences with respect to mental rotation seems to join with the notion inherent in the literature on spatial cognition that some subjects tend to adopt similar preferences for either of the operations of visualization or orientation. In other words, Hock and Ross's structural subjects may have been performing the mental rotation operation much in the same egocentive style as those subjects who projected their body image into the boats in the Ship's Orientation task. The analytic subjects, however, as evidenced by the stimulus prefamiliarization non-effect, seemed to be performing the task in a qualitatively different fashion, perhaps utilizing verbal formula, or at least not enacting orientation operations.

Sex differences also seem to be important. Research has consistently pointed to the fact that men invariably out-perform women on tests for spatial ability (Fruchter, 1954; Smith, 1966; Fairweather, 1976), although some research has not determined the locus of the masculine advantage. Allen (1974) found results directly applicable to the present study. Men scored higher on all tests of spatial ability except those that we can classify as measures of spatial visualization and men were most superior on tests of spatial orientation. On the basis of strategies subjects reported using in solving the tasks, Allen hypothesized that females were less efficient in this regard; often adopting an abstract approach to a difficult problem, failing and substituting a very concrete strategy in its place. The results show that women performed nearly as well as men on the more abstract tests of spatial visualization and that the male superiority (or female deficit) was primarily on the test of orientation--a more concrete test. Allen, however, did not classify her tests on this dimension and therefore, was unable to make any conclusions regarding her research. However, in terms of the twin-factor distinction, the suggestion is that women tend to adopt the visualization factor to the exclusion of the orientation factor.

Contemporary Theories of Spatial Cognition

Until very recently, there existed no reasonably comprehensive theory of spatial cognition. In the last five years, two theorists, one from the school of thought emphasizing discrete, propositional memory representations, and the other emphasizing holistic, imaginal representations, have offered computer simulation models of human spatial cognition.

Minsky's (1975) model rests upon the fundamental assumption that man possesses a cognitive structure that is alterable by experience, and in turn, guides behavior. This view bears obvious resemblance to the schema theories of Bartett (1938) and Piaget (1967, 1971). Minsky's theory is an improvement, however, in that it breaks the schema into components which allows study of the nature of internal representations of discrete events or objects. Minsky has developed a unit of analysis called a frame. A frame represents a rather large chunk of information, much larger than the chunks which cognitive psychologists are used to dealing. In terms of spatial cognition, a frame would represent the visual information one has acquired about all possible views of an object array. Using the representation of a house as an example, the views that one has of the four walls of a room in the house might be considered to be represented in one frame. The individual views are called view frames. Other rooms would, of course, be registered in other frames, and these frames could be grouped into larger frame systems according to section of the house, function, etc. These frames are thought of being arranged in the intersections (nodes) of a network of connecting links. This network of frames is itself a frame called the Global Spatial Frame (GSF) and represents the skeleton spatial arrangement of objects in a large scene of geographical area. It might be considered analogous to an overhead view or cognitive map of an area.

A search through memory for the location of an unseen or occluded object takes place along connecting links of the GSF. The links contain information about how the frames are arranged in external reality (that frame is behind and to the left of this frame, etc.). When the higher frame has been found in the GSF, then particular view frames can be enacted and translated into concrete visual imagery.

The two-factor distinction is readily apparent in the discussion of the functions of the GSF and view frames. The GSF contains information about the arrangement of object arrays with respect to one another, while view frames contain information about the orientation of the objects with respect to the subject's position. The crucial distinction, as with visualization and orientation, is whether or not the position of the subject is inherent in the information provided by the operation.

This theory does allow us to make some predictions as to the time it would take to generate various views of the interior of a house. Since the views of walls of each room are represented in distinct frames, which themselves are linked by associative pathways, it should take longer to generate views of walls in rooms further from one's position (or referent point) than in some section of the house (nearer to one's position or referent point). Although this prediction has not been tested, Kosselyn's research on the scanning of visual images would seem to support it. It is also possible to hypothesize about the time it would take to generate view frames. Based on earlier discussion of the orientation operation as the locus of individual differences, it may be that some subjects may differ in the time they take to generate view frames of an object that requires a change in perspective, i.e., to visualize the opposite side of the wall. Kosselyn's study (1974) discussed earlier confirms this prediction on a developmental level, in that children had more difficulty in estimating the distance between objects separated by barriers.

Kosselyn (1977) has put forth another computer simulation model of spatial cognition. The main feature is his treatment of images as surface products of deep structure transformation, much as is popular in linguistic theory. The deep structure representation of an object consists in Kosselyn's model of two types of storage files. One type contains iconic material about the appearance of the object. This type of file also always contains information about the overall or global appearance of the object. The other type of file stores propositional statements describing the relationship between the object and other objects contained in separate storage files. Image generation takes place as a series of operations which shift about and transform the contents of these files. First, somehow the appropriate global image file is accessed in memory and transformed into a visual image. (Kosselyn uses the metaphor of a computer program generating images on a cathode ray tube, as in a complex television set). Details of this image are then filled in as more iconic files are transformed. Objects associated with the first object are then accessed based on the information contained in the proposition files associated with the first object, until the image is complete. Besides image generation, Kosselyn points out that the location and distance of objects can be determined via a process of "zooming" and "scanning" in which imagined attentional space is devoted to successive parts of a global image until the sought for part is found. Thus, although based upon entirely different processes, Kosselyn's model also predicts longer times to generate distant objects. Kosselyn also notes that an expected prediction of his model would hold that it should be difficult to add details to a global image generated in a non-standard orientation. The reason is that the operations sending iconic material to the rotated image displayed on the surface "screen" would have to accomplish some fairly complex pattern recognition before it could be matched properly. The recognition process at every step of the way would seem to be very uneconomical.

Thus, the operations of visualization and orientation seem to reassert themselves in the model too. The generation and scanning of images takes time such as would a visual search of the corresponding real-life scene. It also takes longer to deal with views of an object requiring a shift in egocentric perspective. Kosselyn's model also provides a new slant on this second operation. Because details are not quickly forthcoming for non-standard views, then for subjects relying heavily upon concrete imagery it should take even longer to generate or make decisions concerning views of this type of environments that are homogeneous rather than distinctive. There does not seem to be any research to address itself to such a prediction, although some will be forthcoming here.

General Conclusions

Two theories of spatial cognition seem to be in agreement on the basic applications involved in generating information about distant objects in the environment. The further the object is from the observer's objective position in space, the more time should be required to generate an image of it. If the image is stored or accessed in a perspective differing from the observer's current one, then even more time should be required to generate it. This last prediction however may not hold true across all subjects due to individual differences associated with the ability to access and generate images of rotated objects.

CHAPTER II

THE STUDY

A reaction time methodology is proposed that is designed to identify the mental operations involved in spatial cognition of an environmental array. It is predicted that the time to visualize designated walls of a house varies according to task and subject parameters. Specifically, it should take longer to visualize a wall hypothesized to be represented in a different frame (room) from the wall in the current visual scene (same room). Analysis of the walls of a house, in terms of frame theory (Minsky, 1975), suggests that walls within a room should be considered to be represented and accessed together. Therefore, given that one is viewing a wall within a house, it should take significantly longer to generate or determine views of the walls of the room just on the other side of that wall than it does to determine walls of the room in which one is currently "in."

Qualitative differences in representation should also have effect on reaction time. For some subjects, it should take longer to determine views of walls which require a change in visual perspective from the one inherent in the given visual scene. Thus, it should take more time for some subjects to generate views of the other side of a wall than the far wall of the next room due to the fact that they may have difficulty in imagining a mental rotation of the body. Other subjects, not lacking this deficiency, may require equal amounts of time to generate each of these extra-room views, or even less time to generate the view of the other side of the wall they are looking at, because they are adept at the mental rotation operation.

These formulations have the assumption that the person would perform such a task by imagining himself as being within the house and mentally traveling through walls and turning around, etc. It is equally conceivable that people might imagine the house as from a bird's-eye perspective. In this case one would simply scan the house, taking more time to generate information about walls as they exist further from a referent point or wall. The existence or absence of an orientation operation would not seem to come into play here. It may be possible to correlate performance on such tasks with preformance on tests of the two abilities associated with spatial ability, orientation and visualization.

To test these hypotheses, a miniature (3 feet square) representation of a four-roomed house was constructed, the rooms being arranged in a square as indicated in Figure 3 (a more detailed diagram is shown in Appendix A).

There are formally possible three "views" of interest that one can generate of the walls within the "dollhouse." Given that one was looking at Wall S (for stimulus wall) from within room 1 at position P, then one could determine the wall one would see if his body were turned 180°, or what we will call the "Reverse" view (Wall R). One could also determine the wall one would see if one suddenly acquired x-ray vision (Wall X). This is, quite appropriately, the "x-ray view." Finally, one could determine the wall one would see if one were to pass through Wall S and then turned around (Wall O). This is the "opposite" view.

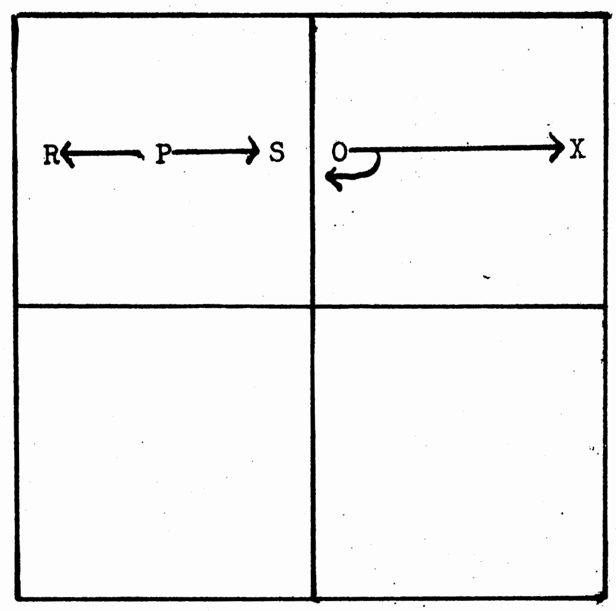


Figure 3. Schematic Diagram of a "Dollhouse"

Based on frame theory, the walls of a room should be represented together. It should thus take longer to generate the x-ray (X) and opposite (O) views than the reverse (R) view. In addition, for some subjects, it should take longer to generate non-standard views (O) than standard views (X), because O requires the enactment of two operations, "walking through the wall" and "turning around," while X requires "walking through the wall" only. Said in another way, some subjects may possess little ability to perform mental perspective change and thus take much longer to generate the O from the X views. On the other hand, some subjects may be able to shift perspectives quite adequately in addition to being able to visualize a complex scene. These subjects might be able to scan the "dollhouse" as from a bird's-eye aerial perspective and since the x-ray wall would be farther from the stem wall than the opposite wall, these subjects should take longer to scan to the X than to the O wall. This prediction would hold true even if they imagined themselves within the dollhouse. A third group of subjects, possessing little power of visualization (and presumably orientation), should perform the spatial task in a non-spatial manner or via direct association, yielding no appreciable differences between x-ray and opposite.

The tests for orientation and visualization were administered in the hopes that they would allow prediction of the above RT patterns. The specific predictions would be that subjects scoring low on the test of orientation would take longer to generate the extra-room wall requiring a perspective change (O) than the extra-room view not requiring that mental operation (X). Subjects scoring high on the orientation test would be able to enact the perspective change quickly and thus take longer to generate X than O simply because X is further from the referent wall. A third group of subjects should show no appreciable differences between X and O due to their reliance upon verbal associations to perform the task.

Method

Subjects

The subjects were 32 students (16 males and 16 females) enrolled in Introductory Psychology courses at Oklahoma State University.

Apparatus

Two random access slide projectors were used to present stimuli onto a rear projection screen. Mounted below the screen was a stimulus cue device designed to light up the words "X-RAY," "OPPOSITE," "REVERSE," and "IDENTITY." Another cue device presented the words "CORRECT" and "INCORRECT." Stimulus events and data storage were controlled by a 1800 E Automated Data Systems process control computer.

Materials

Subjects viewed an experimental space designed to resemble a house. The "dollhouse" consisted of four rooms each measuring 17 inches on a side and all arranged into a square house, in the pattern of Figure 3. The walls of each room were of a different color and the furniture was constructed from cardboard and spare parts. Stimuli were photographic color slides of each wall taken from ground level, with the field of view being taken completely up by the entire wall and not containing any part of the adjacent walls.

Procedure

Instructions read to subjects are included in Appendix B.

Subjects were allowed to view the contents of each room for two minutes. Each room was covered by a removable lid and no two rooms were ever exposed to a subject at once. During the two-minute interval, subjects were instructed to view each wall of each room, standing directly in front of it, for 30 seconds to ensure homogeneous representations and visual perspectives of the dollhouse. After the viewing time was over, the room was covered with the lid, and E tapped on the lids of the rooms by each wall, asking the subjects to recall a unique feature of each wall. If the subjects could not recall a wall, then the lid to that room was removed momentarily to allow another look within. Errors to the criterion of perfect recall were recorded for each subject.

Subjects were then taken to the main laboratory. There the E presented 4 x 6 color photographs of the walls of the dollhouse to each subject, and he/she was asked to point to the corresponding location of the wall on a schematic diagram of the dollhouse. Errors were recorded, and if the subject could not correct an error or if he/she committed more than three initial errors, he/she reviewed the actual dollhouse.

Subjects were then informed that there were three "views" with respect to the dollhouse that were of interest: x-ray, opposite, and reverse. If the subject indicated that he/she understood the views, then all of the photographs of the walls of the dollhouse were laid in front of him/her and he/she was asked to pick up the appropriate one when the E pointed to a photograph and asked for one of the views. Errors were recorded.

The sequence of events of the experimental session for each subject was as follows. The subject was seated in front of a table upon which was a reaction-time switch that could be thrown to indicate a "yes" or "no" decision, a back projection screen, and two random-access projectors. The structure of a single trial is shown in Figure 4. A cue light projecting either the letter "X," "O," or "R" (or "I," to be explained), informed the subject that he/she was free to begin a trial and that that particular view was needed. The subject was then free to depress a foot-switch which caused a slide of an interior wall of the dollhouse to appear on the screen. When the subject felt that he/she knew or had generated the appropriate view, the foot was removed from the foot-switch, at which point the time that the foot-switch was depressed was recorded. This served to define the viewing time (RT1) for slide 1. This act also caused a second slide, either of the correct view or another wall of the room containing the correct view, to appear on the screen. A throw of the response switch to either "correct" or "incorrect" removed that slide from the screen and recorded the amount of time it was visible (RT2). The subject repeated this process for 64 trials (16 per four conditions), which exhausted all possible slide pair combinations, both true and false, for all four conditions or views (remembering that only the 8 walls facing out of the dollhouse have X, O and R views). The order of conditions was random, with the restriction that no view appeared three times in succession.

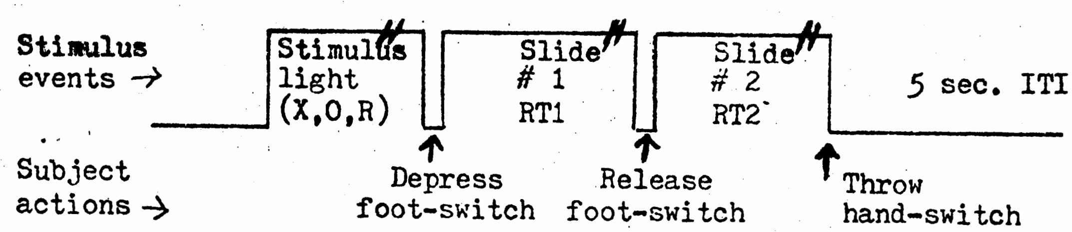


Figure 4. Events Within a Single Trial

The identity condition was added as a baseline indicator; the task was to decide whether or not the second slide was the same as the first. There were also 16 warmup trials at the start of both day's testing which included four trials from each task.

Subjects were administered printed tests for those operations thought to be most relevant to this task: spatial orientation and spatial visualization. Presentation order of the tests was random across subjects. The tests of Ship's Orientation and Punched Holes referred to earlier were used.

Design

Analysis of the data proceeded along three fronts. First, the effects of four factors upon each of the dependent variables of RT1 and RT2 were analyzed. Those factors were composed of three levels of Task (X, O, and R), two levels of Sex, two levels of Days tested, and two levels of Sessions per day. Second, an attempt was made to predict RT1 for each of the three tasks from the scores subjects made on each of the two tests administered to each subject (Punched Holes and Ship's Orientation), in addition to errors made in learning the dollhouse, identifying the slides of the walls of the dollhouse, and learning the tasks. This called for a multiple step-wise regression analysis for predicting RT from various pre-experimental measures of ability and performance. Table 1 illustrates more clearly the variables involved in this analysis and the phase of the study in which they were monitored.

Last, subjects were divided into three groups, depending on whether their means on RT1 for the two tasks exhibited the following response time relationships over both days of testing: 1) $R < X < O$, or 2) $R < O < X$. The third possibility was the case where the relationship between X and O were inconsistent or neglible, 3) $R = X = O$. Subjects in the first group (RXO) were hypothesized not to be preferentially utilizing the orientation operation while those in the second group

TABLE I

DATA MATRIX OF DEPENDENT AND INDEPENDENT VARIABLES

	Day 1	Day 2
Phase 1 Errors in determining geographical orientation	S's	--
Phase 2 Errors in identifying walls by recalling items of furniture	S's	--
Phase 3 Errors in identifying slides	S's	--
Phase 4 Errors in learning task	S's	--
RT1 RT2	S's	S's
Test Scores 1) Ship's Orientation 2) Punched Holes	--	S's

(ROX) were. Subjects in the last group might have been relying on non-spatial processes. To test these notions a discriminant function analysis was performed in order to discover whether subjects in any group score differentially higher on one or more of the tests. It was thought that group one (above) would score relatively lower on the test of orientation than group two.

CHAPTER III

RESULTS

General Findings - AOV

Dollhouse/task learnings are contained in Appendix C.

An analysis of variance for RT1, excluding the identify condition, is summarized in Appendix D. Plots of R1 task means (including Identity) over four sessions are in Figure 5. Session and marginal task means for RT1 and RT2 are shown in Appendix E. The high significance of Session and Day factors reflect expected learning effects. A planned comparison of the task factor revealed that the average mean of X-ray and Opposite combined was significantly greater than Reverse [$T(32) = 2.87$, $p < .005$]. The planned comparison of Opposite and X-ray proved non-significant [$T(32) = .60$, $p > .05$]. The only significant interaction was for Sex by Session, and not of theoretical interest. With regard to Sex differences, it is interesting to note that Opposite exceeded X-ray over all four sessions for males, while the reverse arrangement was true for females (all non-significant at $p > .05$).

Analysis of variance for RT2 (excluding Identity) is summarized in Appendix F. A plot of task means (including Identity) over sessions is included in Figure 6. Tukey's post-hoc analysis of the task factor revealed a significant difference between X-ray and Opposite

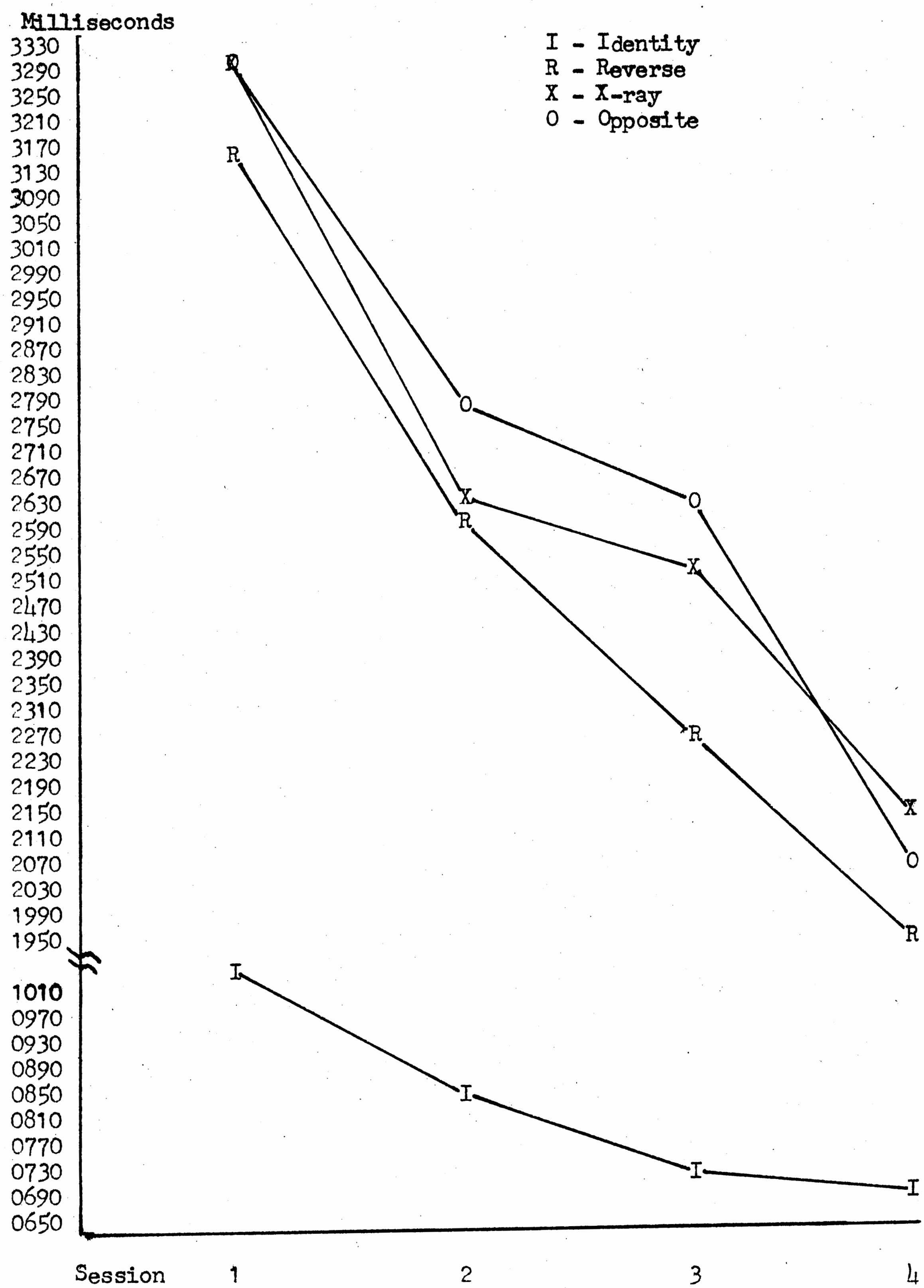


Figure 5. Plot of RT1 Task Means Over Four Sessions

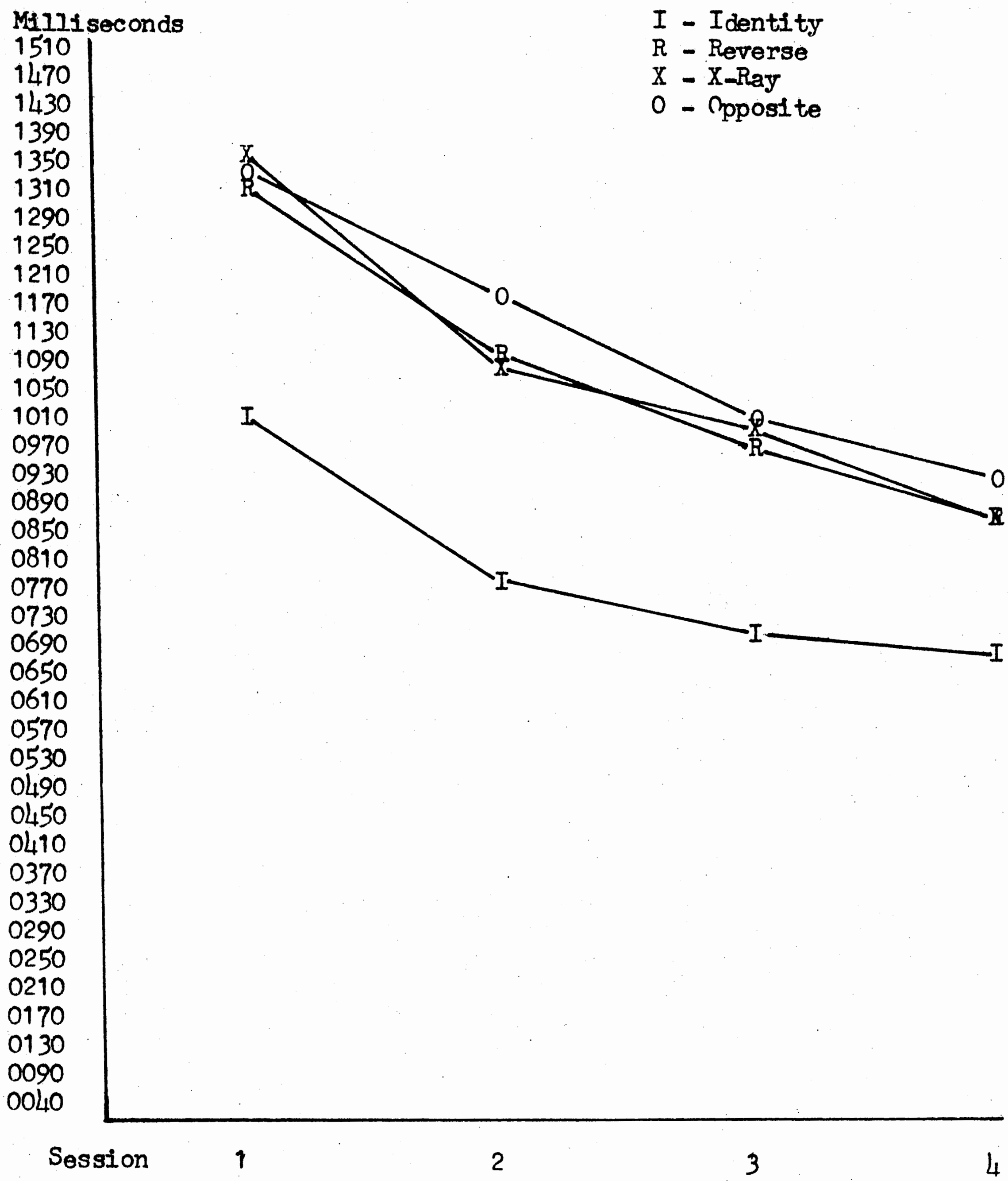


Figure 6. Plot of RT2 Task Means Over Four Sessions

[$T(60) = 5.34$, $p < .05$]. Simple main effects analysis of the Task factor showed significance for Task at Session 2 [$F(2,60) = 4.31$, $p < .01$]. Post-hoc analysis indicated significance differences between Opposite and X-ray [$T(60) = 3.71$, $p < .05$], and Opposite and Reverse [$T(60) = 3.32$, $p < .05$].

It should be noted that these means for RT1 and RT2 are pooled over correct rejection and correct acceptance choices. Data points not falling within maximum and minimum cut-off criteria (Appendix G), or falling within two standard deviations from the subject's Task per session RT mean of the remaining data, were removed from consideration. This usually meant removing one or two data points per Task per Session, and considering an equivalent number of errors (Appendix H), this left an average of twelve data points on which to base Task means. An analysis of error scores revealed no significant Task differences (Appendix I).

General Findings - Correlations

Correlations among RT1 Tasks (Reverse, X-ray and Opposite), dollhouse/Task learning phases, and tests of Visualization and Orientation are contained in Table II. The inter-Task correlations were high and virtually identical. The test of Visualization, and not Orientation, bore moderate negative correlations with all Tasks.

Both tests correlated, from high to low, with Reverse, Opposite, and X-ray. The r for Orientation and Reverse is significantly greater than that for Orientation and X-ray [$T(32) = 2.22$, $p < .05$].

TABLE II

CORRELATIONS AMONG RT1 TASKS, TESTS, AND DOLLHOUSE/TASK LEARNING PHASES

	Reserve	X-ray	Opposite	Orientation	Visualization	(Direction) Phase 1	(Remember Walls) Phase 2	Task (Contract) Phase 3	Task (Concrete) Phase 4
Reverse	r=1.00 p .00								
X-ray	r= .82 p .0001								
Opposite	.90 .0001	.89 .0001							
Orientation	-.30 .09	-.21 .24	-.28 .11						
Visualization	-.54 .002	-.47 .006	-.51 .003	.66 .0001					
Phase 1	-.04 .81	-.26 .14	-.15 .60	.20 .28	.12 .53				
Phase 2	.12 .53	.07 .70	.15 .58	-.54 .002	-.36 .04	.01 .95			
Phase 3	.55 .001	.38 .03	.49 .005	-.32 .07	-.29 .10	-.01 .94	.28 .11		
Phase 4	.19 .31	.27 .13	.24 .193	-.27 .13	-.05 .76	-.14 .54	.43 .01	.23 .20	

Individual Differences

Subjects' data were then classified into three ad hoc groups, depending upon whether, for at least three out of four sessions, the mean for Opposite exceeded X-ray (Group 1, n = 14), X-ray exceeded Opposite (Group 2, n = 11), or there was no agreement for three sessions (Group 3, n = 7).

A discriminant function analysis of group membership based upon test scores revealed relatively no predictive validity for the above criteria. The prediction function eigenvalue for the test of Orientation was .03 [$\chi(4) = 1.4$, $p > .05$], and for the test of Visualization, .02 [$\chi(1) = .44$, $p > .05$].

Task-test correlations of the three groups are shown in Table III. The test of Visualization only bears significant correlations with all three tasks for Group 1, while the test of Orientation alone does so for Group 2.

TABLE III

TASK-TEST INTERCORRELATIONS FOR THREE AD HOC GROUPS

	Reverse	X-ray	Opposite	Orientation	Visualization
Group 1 OSX n = 14					
X-ray	.91 P .0001				
Opposite	.90 .0001	.96 .0001			
Orientation	-.35 .22	-.35 .23	-.34 .24		
Visualization	-.59 .03	-.69 .006	-.64 .01	.71 .005	
Group 2-X 0 n = 11					
X-ray	.79 .004				
Opposite	.78 .005	.95 .0001			
Orientation	-.77 .006	-.62 .04	-.70 .02		
Visualization	-.66 .03	-.41 .21	-.51 .11	.84 .002	
Group 3-X=0					
X-ray	.98 .0003				
Opposite	.97 .0007	.98 .0004			
Orientation	.703 .08	.71 .07	.61 .15		
Visualization	-.40 .62	.38 .59	.47 .30	.085 .850	

CHAPTER IV

DISCUSSION

There were two classes of hypotheses: one having to do with general operations in spatial cognition, the other dealing with individual differences, both of which were at least partially supported.

First, it was predicted that subjects would take more time to generate, from memory, information about walls of the dollhouse that were not physically visible from a referent point (X-ray, Opposite) than about walls that were (Reverse). The rationale for such a prediction seems to follow from current models of spatial cognition which emphasize longer retrieval times for information about scenes that are represented in different rather than similar "frames" (Minsky, 1975). Frames should, in this case, correspond directly with representations of the four walls of a room. The finding that it takes significantly longer to generate (RT1) extra-room views (X, O) than the same room walls (R) firmly supports this notion.

No predictions had been made for RT 2 Task means. The fact that the Task means generally mimiced RT1 suggests that the double reaction-time technique is not perfect in separating out experimental and decision Task components.

Previous researchers on spatial cognition emphasized an individual difference view of spatial cognition, contending that there were several mental operations involved in solving a spatial task and that they could be utilized in differing proportions by different people. Michael et al. (1957) discovered psychometric evidence for two main spatial operations: Orientation, which referred to the ability to imagine an object array from different perspectives, and Visualization, which referred to the general ability to hold or manipulate in one's mind the image of an object array. With respect to these tasks, the X-ray viewer does not require a perspective change while the Opposite and Reverse do. Thus any individual differences should be linked to differential performance on these two classes of Tasks. Current models of spatial cognition do not explicitly postulate separate spatial operations, probably because both experimentally and theoretically, the notion has been debated (Smith, 1964; Pawlik, 1966). These data, however, unambiguously indicate wide individual differences with respect to these Tasks. First of all, there were 14 subjects who regularly took significantly more time to generate the Opposite than the X-ray view, while another 11 subjects indicated the Reverse tendency. Second, the correlational patterns of these two groups were markedly different, although unexplainably so. Due to the small n sizes of the groups, conclusions must be postponed in lieu of further research. But it is clear that a comprehensive theory of spatial cognition will have to account for the very substantial individual differences.

Whatever conclusions that may be drawn from the attempt to integrate psychometric tests of spatial cognition with information-processing Tasks, it is clear that, from the low Task-test correlations, the two are tapping different cognitive components. At least from the results of this experiment, Carroll's (1976) hope of "forging a link between psychometric data and cognitive information processing theory" (p. 28), may not be soon forthcoming.

In summary, these data indicate the usefulness of a particular information-processing methodology for the study of mental operations involved in the cognition of real-world spatial scenes.

BIBLIOGRAPHY

Allen, M. J. Sex differences in spatial problem-solving styles. Perceptual & Motor Skills, 1974, 39, 843-846.

Angyal, A. Uber die Raumlage vorgestellter Orter. Arch. Ges. Psy., 79, 47-94. In I. P. Howard and W. B. Templeton, Human Spatial Orientation. London: John Wiley & Sons, 1966.

Bartlett, F. C. Remembering: A Study in Experimental and Social Psychology. Cambridge: Cambridge University Press, 1932.

Carroll, J. B. Psychometric tests as Cogntive Tasks: A New Structure of Intellect." In L. B. Reinick (Ed.), The Value of Intelligence. Hillsdale, NJ: Lawrence Grebaum Associates, 1976.

Cattell, R. B. Abilities: Their Structure, Growth and Action. Boston: Houghton Mifflin Co., 1971.

Claparede, E. Note sur la localisation du moi. Arch. Psy. Geneve, 19, 172-182. In I. P. Howard and W. B. Templeton, Human Spatial Orientation. London: John Wiley & Sons, 1966.

Fairweather, Hugh. Sex Differences in Cognition. Cognition, 1976, 4, 231-280.

Fruchter, B. Measurement of spatial abilities: history and background. Educational and Psychological Measurement, 1954, 14, 387-395.

Gregg, F. M. Are motor accompaniment necessary to orientational perception? The Journal of Psychology, 1939, 8, 63-97.

Guilford, J. P. The Nature of Human Intelligence. New York: McGraw-Hill, 1967.

Guilford, J. P. and R. Hoepfner. The Analysis of Intelligence. New York: McGraw-Hill, Inc., 1971.

The Guilford-Zimmerman Aptitude Survey. Part V Spatial Orientation Form A. Beverly Hills, CA: Sheridan Supply Co., 1947.

Hart, R. A. and G. T. Moore. The development of spatial cognition. In R. M. Downs and D. Stea (Eds.), Image and Environment. Chicago: Aldine Publishing Co., 1973.

Hochberg, J. and L. Gellman. The effect of landmark features on mental rotation times. Memory & Cognition, 1977, 5(1), 23-26.

Hock, H. and K. Ross. The effect of familiarity on rotational transformation. Perception & Psychophysics, 1975, 18(1), 15-20.

Howard, I. P. and W. B. Templeton. Human Spatial Orientation. London: John Wiley & Sons, 1966.

Kosslyn, S. M. Scanning visual images: some structural implications. Perceptions & Psychophysics, 1973, 14(1), 90-94.

_______. Constructing visual image. (Unpub. dissertation, Stanford University. 1974).

Kosselyn, S. M. and J. R. Pomerantz. Imagery, propositions, and the form of internal representations. Cognitive Psychology, 1977, 9, 52-76.

Metzler, J. and R. N. Shepard. Transformational studies of the internal representation of three-dimensional objects. In H. L. Solso (Ed.), Theories in Cognitive Psychology: The Loyola Symposium. Potomic, MD: Lawrence Erlbaum Associates, 1974.

Michael, W. B., J. P. Guilford, B. Fruchter, and W. S. Zimmerman. The description of spatial-visualization abilities, 1957, 17, 185-199.

Michael, W. B., J. P. Guilford, and W. S. Zimmerman. An investigation of two hypotheses regarding the nature of the spatial-relations and visualization factors. Educational and Psychological Measurement, 1950, 10, 187-212.

Minsky, M. A framework for representing knowledge. In P. H. Winston (Ed.), The Psychology of Computer Vision. New York: McGraw-Hill Book Co., 1975.

Neisser, U. Cognition and Reality. San Francisco: W. H. Freeman and Company, 1976.

Paper Folding Test - V2-2. Educational Testing Service, 1962.

Pawlik, K. Concepts in human cognition and aptitudes. In R. B. Cattell, Handbook of Multivariate Experimental Psychology. Chicago: Rand McNally & Co., 1966.

Piaget, J. and B. Inhelder. The Child's Conception of Space. London: Routledge & Keagen Paul, 1956.

_______. Mental Imagery in the Child. New York: Basic Books, Inc., 1971.

Rock, I. Orientation and Form. New York: Academic Press, 1973.

Ryan, T. A. and M. S. Ryan. Geographical orientation. American Journal of Psychology, 1940, 53, 204-215.

Shepard, R. N. and C. Feng. A chronometric study of mental paper folding. Cognitive Psychology, 1972, 3, 228-243.

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

Smith, I. M. Spatial Ability. San Diego: Robert R. Knapp, 1964.

Spearman, C. Abilities of Man. New York: Macmillan & Co., 1927.

Thorndike, E. L. On the organization of the intellect. Psychological Review, 1921, 28, 141-151.

Thurstone, L. L. Primary Mental Abilities. Psychometric Monographs No. 1, 1938.

Trowbridge, C. C. Fundamental methods of orientation and imaginary maps. Science, 1913, 38, 888-897.

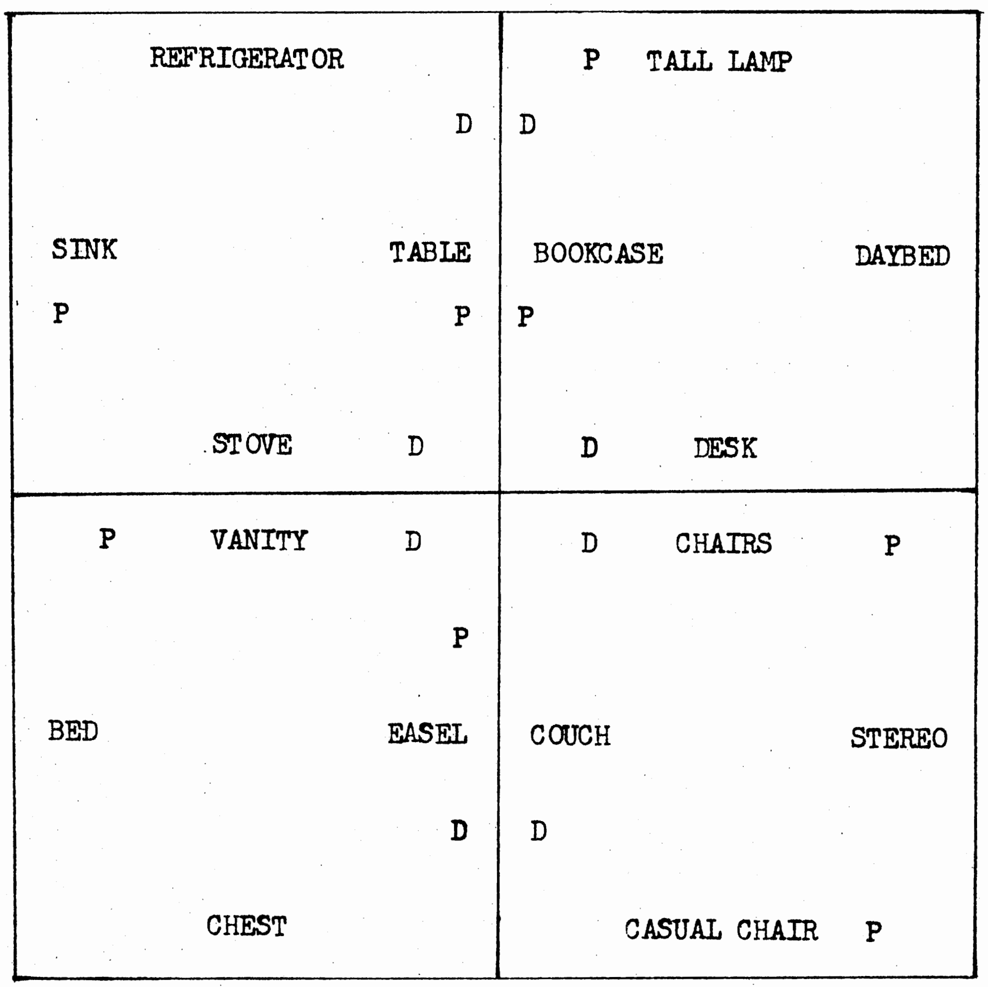
Vandenberg, S. G. A twin study of spatial ability. Multivariate Behavior Research, 1969, 4, 273-294.

Yen, W. Sex-linked major-gene influences on selected types of spatial performance. Behavior Genetics, 1975, 5(3), 281-298.

APPENDIXES

APPENDIX A

DOLLHOUSE FURNITURE ARRANGEMENT[1]



[1]Key

P - Painting

D - Door

APPENDIX B

INSTRUCTIONS TO SUBJECTS UPON LEARNING THE DOLLHOUSE

Phase I

1. E ascertains that subject is aware of polar coordinates and locations of landmarks about the campus. Errors in noting the correct orientation will be recorded and corrected.
2. E reads instructions:

"This is an experiment investigating the general question of what psychological processes are involved in learning one's environment, or more generally; how does one know where he is and where things are around him or her.

In order to do this we have constructed a miniature representation of a four-roomed house, each room being covered by removable lid. I will remove each lid in turn during which you will have two minutes to inspect the room within. After looking at all four rooms you will be shown pictures of each of the walls of the dollhouse and asked which wall in which room they show. After we are sure that you have learned the dollhouse, you will be asked to perform in an experiment in which the task involves viewing pictures of two walls and making a quick decision as to where one wall is in relation to the other. So it is not so important that you remember every piece of furniture in a room, but rather be able to remember the arrangement of the walls of the dollhouse while looking at pictures of them."

3. E continues with instructions:

   "Please stand by the dollhouse here (E points). When I lift the first lid you should begin your inspection. You will have two minutes per room. Every 30 seconds I will indicate that you should move to the next slide of the dollhouse where you will continue viewing the same room from another angle."

4. E removes the first lid and identifies the room as per kitchen, study, LR, or BR.

5. After the subject has viewed all four rooms, the experimenter asks him/her to name an identifying feature on each wall as the experimenter indicates them at random by tapping the roof of the dollhouse. When all the walls are correctly identified by this method, phase 1 is completed. Errors are recorded for each subject. If there is an error within a room, the subject is allowed to review the room associated with the error immediately for 30 seconds.

<u>Phase 3 (Slide Identification)</u>

1. E places a schematic diagram representing an aerial view of the dollhouse before the subject and asks him to point to the appropriate wall as photographs of each wall are placed before the subject. This process continues until the subject correctly identifies each photograph. Errors will be recorded and photographs associated with errors will be shown again until all are correctly identified.

Phase 4 (Familiarization with the Task)

"As I mentioned earlier the experimental task involves viewing pairs of slides of the walls of the house and determining if they bear a certain relationship. If you will look at the diagram I will explain what those relationships are. If, after looking at the wall in front of you, you turned around or reversed your position by 180 degrees you would of course be facing the wall behind you. Now, if you were again looking at this wall and you acquired the power of X-ray vision you would see the far wall of the next room, as you can when I open this door. Now, if after looking again at the wall in front of you you were to go through the door into the next room and turned 180 degrees you would be facing the near wall of the next room or the opposite side of this wall. Thus when looking at a wall it is possible for you to determine what we will call the reverse view, the X-ray view, and the opposite view.

AT THIS POINT THE EXPERIMENTER SHOULD QUESTION THE SUBJECT TO MAKE SURE HE UNDERSTANDS THE THREE TASKS. IF HE INDICATES THAT HE DOES, THE E SHOULD LAY ALL OF THE WALL PHOTOGRAPHS BEFORE THE SUBJECT. FROM ANOTHER DECK OF PHOTOGRAPHS THE E SHOULD PRESENT ONE AT A TIME, EACH TIME ASKING FOR ONE OF THE THREE VIEWS. THE SUBJECT SHOULD PICK UP THE APPRIATE PHOTOGRAPH FROM THOSE IN FRONT OF HIM. ERRORS SHOULD BE RECORDED. IF A SUBJECT CANNOT CHOOSE CORRECTLY AFTER ONE ERROR, OR IF HE MAKES MORE THAN THREE INITIAL ERRORS, THEN THE VIEWS SHOULD BE EXPLAINED AGAIN. IF THE SUBJECT STILL CANNOT ACHIEVE CRITERION, HE SHOULD BE RETURNED TO PHASE 3.

Phase 5 (Familiarization with Task Sequence)

"When one of the task lights before you lights up, you are free to begin. When you are ready you will depress one of the two handswitches on either side of the control switch in either direction in front of your chair (E points) at which point a slide will appear on the screen in front of you. As long as you hold the handswitch down, the slide will remain on the screen. You are then to determine the point of view indicated by the stimulus light given that you are looking at the slide on the screen. When you feel that you know what the appropriate view is, you quickly remove your hand from the switch. At this point the slide will disappear from the screen and another slide will appear in its place. This second slide will either be the correct view or it will be another incorrect view. If it is the correct view, you should throw the central hand switch in front of you in the direction indicated by the word "yes." If it is the incorrect view you should throw the switch in the direction indicated by the word "no." In either case, after you throw the switch, the second slide will disappear from the screen. After about one-half second one of the stimulus lights will light up again and you will be free to begin the process again.

Also intermixed with the views will be a few trials where the task will be to decide if the second slide is the same exact slide as the first slide. If it is, you will decide "yes," and if it is not, you will respond "no." These trials will be indicated by a stimulus light marked "identity." The lights marked "correct" and "incorrect" will inform you if your decision was correct.

APPENDIX C

MEAN ERRORS MADE IN LEARNING PHASES

	1 Directions[1]	3 Furniture	3 Task/ Diagram	4 Task/ Pictures
Mean	Yes - 26	5.25	.94	.56
S.E.	No - 6	3.84	2.20	1.54
Possible	(3 trials)	48	18	18

[1]Frequencies

APPENDIX D

AOV FOR REACTION TIME 1

Source	df	SS	MS	F
Sex (X)	1	4.2313	4.2313	0.5340
Task (T)	2	3.0399	1.5200	4.2386*
Day (D)	1	46.4528	46.4528	84.0553**
Session [S(D)]	2	24.6987	12.3493	70.2335**
Subjects [N(X)]	30	237.7307	7.9244	
X * T	2	1.4874	.7437	2.0739
X * D	1	.2871	.2871	.5195
X * S(D)	2	1.3141	.6570	3.7367*
T * D	2	.3037	.1519	2.6384
T * S(D)	4	.6117	.1529	1.904
T * N(X)	60	21.5160	.3586	
D * N(X)	30	16.5734	.5526	
S * N(DX)	60	10.5500	.1758	
X * T * D	2	.0323	.0163	.2801
X * T * S(D)	4	.2015	.0504	.6270
T * D * N(X)	60	3.4538	.0576	
T * S * N(DX)	120	9.6400	.0803	

*p .05
**p .0001

APPENDIX E

MEANS FOR RT1 AND RT2 OVER SESSIONS AND TASKS

		I	II	III	IV	Total
RT1 (Sec)						
Reverse	$\bar{X}$ =	3.163	2.594	2.267	1.961	2.496
	S.E.=	.972	.949	.836	.750	.829
X-ray	$\bar{X}$ =	3.304	2.649	2.538	2.161	2.663
	S.E.=	.948	.853	.937	.813	.833
Opposite	$\bar{X}$ =	3.319	2.779	2.629	2.079	2.702
	S.E.=	1.090	.988	.923	.789	.871
Identity	$\bar{X}$ =	1.034	.847	.730	.670	.820
	S.E.=	.346	.338	.217	.177	.233
RT2 (Sec)						
Reverse	$\bar{X}$ =	1.317	1.099	.968	.867	1.063
	S.E.=	.329	.313	.256	.219	.255
X-ray	$\bar{X}$ =	1.366	1.085	1.005	.866	1.080
	S.E.=	.355	.262	.256	.217	.246
Opposite	$\bar{X}$ =	1.333	1.183	1.033	.920	1.117
	S.E.=	.369	.307	.252	.254	.265
Identity	$\bar{X}$ =	1.012	.795	.714	.670	.798
	S.E.=	.260	.176	.158	.160	.175

APPENDIX F

AOV FOR REACTION TIME 2

Source	df	SS	MS	F
Sex (X)	1	.3944343	.3944	.5145
Task (T)	2	.1986	.0993	7.3535*
Day (D)	1	7.9348	7.9348	89.5300**
Session [S(D)]	2	2.9166	1.4583	53.0145**
Subjects [N(X)]	30	22.9995	.76665	
X * T	2	.0354	.01769	1.3095
X * D	1	.2599	.2599	2.9329
X * S(D)	2	.0476	.0238	.8648
T * D	2	.0018	.0091	.0899
T * S(D)	4	.1492	.0373	4.4925*
T * N(X)	60	.8103	.0135	
D * N(X)	30	2.659	.0886	
S * N(DX)	60	1.650	.0275	
X * T * D	2	.0095	.0047	.4675
X * T * S(D)	4	.0548	.0137	1.6494
T * D * N(X)	60	.6071	.0101	
T * S * N(DX)	120	.9963	.0083	

*p .01
**p .0001

APPENDIX G

RT CUTOFF VALUES

(Sec.)

		Task R, X, O	Task I
RT1	Maximum	5.50	2.50
	Minimum	.80	.30
RT2	Maximum	3.50	2.50
	Minimum	.50	.30

APPENDIX H

RT TASK ERRORS

(16 per cell possible)

		1	2	3	4	Total
Identity	$\bar{X}$ =	.531	.219	.188	.094	.258
	S.E.=	.761	.491	.739	.390	.595
Reverse	$\bar{X}$ =	2.063	1.750	1.844	1.031	1.672
	S.E.=	2.078	1.741	1.851	1.257	1.780
X-ray	$\bar{X}$ =	1.750	1.313	1.250	1.156	1.367
	S.E.=	1.481	1.256	1.320	1.273	1.335
Opposite	$\bar{X}$ =	2.406	1.313	1.688	1.344	1.672
	S.E.=	1.847	1.306	1.424	1.125	1.426

APPENDIX I

AOV FOR ERRORS

Source	df	SS	MS	F
Sex (X)	1	17.5104	17.5104	1.4432
Task (T)	2	7.9375	3.9687	1.5556
Day (D)	1	13.5000	13.5000	7.2537*
Session [S(D)]	2	26.0521	13.0260	14.5351**
Subjects [N(X)]	30	363.9790	12.1326	
X * T	2	2.1458	1.0729	.4205
X * D	1	.1667	.1667	.0896
X * S(D)	2	.1771	.0885	.0988
T * D	2	.4375	.2187	.1611
T * S(D)	4	10.2291	2.5573	2.3257
T * N(X)	60	153.0805	2.5513	
D * N(X)	30	55.8333	1.8611	
S * N(DS)	60	53.7708	.8962	
X * T * D	2	1.5833	.7916	.5830
X * T * S(D)	4	3.7916	.9479	.8621
T * D * N(X)	60	81.4695	1.358	
T * S * N(DX)	130	131.9486	1.0996	

*p .05
**p .001

VITA 2

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Master of Science

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