TRANSFORMATION OF MIND'S EYE LOCATION AND VISUAL IMAGE ORIENTATION IN PERCEIVING CUTANEOUS DRAWINGS

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TRANSFORMATION OF MIND'S EYE LOCATION AND VISUAL IMAGE ORIENTATION IN PERCEIVING CUTANEOUS DRAWINGS

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PREFACE

Imagery is an important area of study for a number of reasons. First, many issues regarding the structure and function of images have yet to be clarified. Second, studying the nature of imagery can provide information on the structure of memory, attention, and other more broad aspects of cognitive psychology. Third, understanding the processes underlying imagery provides important information concerning how people solve practical problems in everyday living. This thesis deals with the question of how images are rotated and how a person's mental point of reference is transformed. The processes underlying such behavior have hopefully received at least some clarification.

I wish to express my appreciation to Dr. Robert J. Weber, who served as my Thesis Adviser, for his continual guidance, encouragement and help. Dr. Robert F. Stanners and Dr. William E. Jaynes also served as committee members, and I should like to express appreciation and thanks to them as well.

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

This thesis has been formatted according to American Psychological Association specifications. The deviation from the Oklahoma State University format was used to facilitate publication in the Journal of Experimental Psychology. Permission to use this format was granted by the Graduate College.

Abstract

Two strategies for operating on visual images (image transformation and mind's eye transformation) were studied in the context of cutaneous perception of drawings on the forehead and left side of the head. Twenty-four male and 24 female undergraduates were divided into four balanced groups. All subjects received finger drawings of ambiguous letters (*p*,*q*,*b*,*d*) and identified each drawing after performing one of four mental operations. Reaction times and accuracy in identifying the drawings from their transformed position were measured. Results showed the image transformation strategy both faster and more accurate than the mind's eye transformation. In both transformation strategies, more complex operations took significantly longer than simple operations, especially for the mind's eye strategy. Possible relations between image transformations and allocation of attention resources are discussed.

Transformation of Mind's Eye Location and Visual Image Orientation in Perceiving Cutaneous Drawings

There are two broad geometric strategies a person may use when asked to change the way he or she views a visual image. One way is to hold the mind's eye in one position and rotate the image about some axis; x, y, or z. The second way is to transform the location of the mind's eye and hold the image "fixed" in one place. Although a result of each of these strategies may be functionally identical, the processes used seem quite different.

The concept of a 'mind's eye' is best defined as a simile for the interpretive processes that extract information from the image buffer. These interpretive processes behave _as if_ they are a disembodied eye that can (a) move around the mental representation of the environment or (b) produce or interpret operations on the image representation.

Some real world analogs to this phenomenon may be considered. If an assembly line worker reaches behind an object to install a part, he may mentally visualize what his hand is doing in one of at least two ways. First, he may mentally turn the object around so that he visualizes its back side, or, second, he may mentally keep the object stationary and move his mind's eye behind the object. Both strategies are functionally identical. That is, the worker uses a visual image of the back of the object to aid him in his task.

An automobile mechanic may experience the same phenomenon. His task, though, may be complicated because the mechanic frequently works while leaning over the automobile in an upside down position. The mechanic in the upside down position may use one of the two strategies mentioned above. If he is upside down and reaching behind an object, he may mentally turn the object around and rotate it in the picutre plane so that he sees the back side of the object in an upright position with respect to his head. In this instance he simply keeps his body coordinates fixed and transforms the image. A functionally equivalent strategy would require the mechanic to mentally move his mind's eye to the backside of the object then rotate his mind's eye to an upright position with respect to gravity. Here, the image remains fixed while the mind's eye moves through a coordinate space.

Two experiments related to this problem were performed by Kolers and Perkins (1969a, 1969b). Subjects were to identify strings of letters which were transformed in various ways. The four transformation operations of interest here were normal appearance (N), rotation in the plane of the page (R), mirror reflection (M), and inversion in the depth plane (I). Results showed that identifying letter strings were not equally fast or accurate for different operations. In increasing latency, the order was N, R, M, I. In increasing error scores, the order was N, M, R, I. Differences between M and R in both speed and accuracy were slight if not altogether insignificant. Differences on both accounts between N and I were highly significant. Kolers and Perkins did not discuss in detail whether image transformation or mind's eye transformation was employed as the performance strategy. Either strategy could have been used.

Cooper and Shepard (1973) confirmed that people can transform visual images apparently while holding the mind's eye fixed. They tested subjects on the time to rotate mental images different degrees along the picture plane. Using alphabetic and numeric figures, Cooper and Shepard first presented a stimulus, then after withdrawing it, presented a test figure which was either a mirror image or the same orientation of the original figure. Subjects were scored on the amount of time it took to respond whether the test figure was the same orientation or the mirror image of the original figure. Cooper and Shepard used five different levels of giving subjects prior information about the direction and orientation of the test item. Results from each of those levels of advanced information indicated that the more information a subject had about orientation of the test item, the more diminished were verification times. These results were used to support the argument that mental rotation of visual images can be verified and analyzed, and that the farther one must rotate an image the longer it will take.

In another experiment, Cooper and Shepard (1975) studied the mental transformation of visual images in the depth plane. They used a procedure in which people were asked to recognize whether a drawing of a hand, which was rotated in the depth plane, was a right or a left hand. Subjects were first presented with a schematic drawing of a hand. The angle of rotation which the test stimulus would assume was cued to the subject by a thumbless hand. After the thumbless hand was removed, people were timed while deciding if the test hand was right or left. The hypothesis was that if people flip a visual image of their own hand to help them decide the orientation of the test, then verification times will be longer for trials which require transformations in the depth plane. The results seemed to indicate that people can flip visual images in the depth plane.

Images derived from cutaneous drawings may also be used to study image transformations. In addition, cutaneous stimulation is a method which may be applied to studying the transformation of the mind's eye. This method was first described by Krech and Crutchfield (1958). They stated that if a figure, like the lower-case letter _p_, is traced on the forehead of a subject it can either be perceived as a _p_ or a _q_. If the letter is perceived as a _q_, then the subject experiences the figure from an internal point of view, that is, from a location of the mind's eye inside his or her head looking out. If the letter is perceived as a _p_, then the subject views the image of the letter from an external point of view: that is, from a location of the mind's eye outside his or her head which is similar to the perspective taken by the experimenter. In other words, the subject's mind's eye can be in an internal or external location with respect to the head.

Corcoran (1977) studied the location of the mind's eye in identifying figures drawn on the skin. Assymetrical figures were drawn on the skin at various locations such as various areas of the head, palm of the hand, leg, and back. Corcoran found that figures drawn on the body in front of an imaginary line through the center of the head (vertical plane), approximately in line with the ear canal, were perceived as the mirror image of the experimenter's view. In contrast, figures drawn behind the line were perceived from the same orientation as the experimenter's. It was hypothesized that a translation of the location of the mind's eye resulted in the different perceptions of the figures. If figures were drawn behind the imaginary line, the mind's eye was thought to move to a location behind the subject's head. If figures were drawn in front of the imaginary line, the mind's eye was thought to remain at a default position somewhere inside the subject's head.

A similar study designed to investigate the strategy of translating the mind's eye was reported by Duke (1966). This study used essentially the same procedure as Corcoran. In Duke's experiment a 'frontal-plane' hypothesis was posited to explain the orientation of the perceiver to finger drawings upon the body surface. This hypothesis stated that symbols which are drawn upon the anterior and posterior surfaces of the body are perceived as if they were projected out in front of the subject on a transparent two-dimensional surface. Implicit in this hypothesis is that geometrically the body is a transparent surface and that the locus of perception is from a fixed point behind the subject. The fixed point notion is contrary to Corcoran's moving internal-external origin. According to the frontal-plane hypothesis all body drawings on the anterior surface are viewed as if looking through the body. All body drawings on the posterior surface are viewed as if looking at the back of the body so that a view similar to the experimenter's is taken. Duke's results were interpreted in support for his hypothesis. Unfortunately, his results do not discount the possibility that the mind's eye may translate from one location to another.

An experiment designed in part to distinguish whether the locus from which image perception originates remains fixed behind the head (frontal-plane hypothesis) or whether it shifts between the inside and outside of the head was performed by Weber and Mankin (Note 1). With a method similar to Duke's, Weber and Mankin used the top of the head and under the chin, along with other skin areas, as sites to trace figures.

If the locus of the mind's eye is fixed behind the head then drawings on the top and bottom of the head were expected to result in neither predominately internal nor external orientations. On the other hand, if regular results were obtained on the top and bottom of the head, then the frontal-plane hypothesis could not be true in general. Weber and Mankin reported that subjects did respond consistently to figures drawn on the top and bottom of their heads. These results supported the contention that the mind's eye can translate from internal to external origins along at least two tracks: up/down and fore/aft.

A curious phenomenon reported by Weber and Mankin was that some subjects identified figures from orientations which could only be explained if the mind's eye was translated to an upside down position. This phenomenon suggested two possible orientations of the mind's eye beyond the internal and external locations previously discussed. These two additional orientations occur when the mind's eye is upside down and is either internally or externally located. Therefore, four possible orientations for the mind's eye in response to cutaneous drawings on the head have been identified: (1) an upright position from inside the head looking out - up/inside, (2) an upright position from outside the head looking in - up/outside, (3) an upside down position from inside the head looking out - down/inside, and (4) an upside down position from outside the head looking in - down/outside.

In a pilot study, Mankin and Fiebig tested subjects on the speed at which they could assume the four orientations listed above. Letters (p, q, b, d) were traced on each of four sides of a subject's head (forehead, back, left side, or right side). Subjects were asked to assume one of the four orientations (up/inside, up/outside, down/inside, down/outside) immediately after a test letter had been drawn. The fastest reaction times occurred when the instructed orientation coincided with what could be considered a natural, or 'default', orientation for each of the four sides of the head. Appendix A gives a table of means for this pilot data. The results were used to support the contention that it takes a longer time for the mind's eye to transform its location and orientation to a position other than the default position and that the greater the cognitive effort for the transformation, the longer the time.

Mankin performed a second pilot experiment designed to measure the speed and accuracy with which a person could name figures drawn on the skin. Subjects were first asked to assume one of the four mental perspectives of the mind's eye discussed above before receiving a cutaneous drawing. Subjects were then told to take one of the four mind's eye perspectives on either their forehead, back of the head, left side, or right side. When the subject reported that a clear image of his or her head had been achieved in the instructed perspective, the experimenter drew a letter on that same head area. Subjects were then asked to name the letter as quickly and as accurately as possible while maintaining the instructed perspective.

Midway through the experiment, it was discovered that some subjects were not attempting to create an image of their head prior to receiving the stimulus. Rather than rotating the mind's eye, these subjects simply rotated the image of the letter after it was drawn. The mind's eye, in this case, remained stationary instead of following the instructions to move while holding the letter stationary. These transformations of the letter resulted in a response which was functionally equivalent to the expected response if the subject had transformed the mind's eye.

That is, subjects used one of four possible operations to transform and perceive the image: (1) perceive the letter exactly as it appeared from the default perspective - normal, (2) rotate the letter in the depth plane so that an image equivalent to the mirror image of the letter was seen - mirror image, (3) rotate the letter in the picture plane so that it was upside down in the six o'clock position - upside down, (4) flip the letter in the depth plane so that it was upside down and backwards - mirror + upside down.

The unexpected transformation strategy found in the second Mankin pilot study was reportedly easier for subjects than the strategy given in the instructions. Discovering that some subjects were using this alternative strategy raised the question of whether or not simply transforming the image of the figure is in fact more efficient and effective compared to transforming the location and orientation of the mind's eye.

An important question is raised because of the two functionally equivalent strategies described in the above introduction. This question pertains to the distinction between the mental imagery literature and the cognitive mapping literature. Kosslyn (1980), for example, presented an impressive account of mental imagery theory and experimentation. Others, as early as Tolman (1948) have studied the concept of a cognitive map. Appendix B of this paper will compare theories such as those given by Kosslyn with the literature on cognitive mapping. But for now, the impression involved with a cognitive map is that people change the body coordinates rather than the map coordinates when examining different views of the map.

The purpose of this experiment is to compare two functionally equivalent strategies for transforming visual images. Two image transformation groups will use transformations of the visual image as in the Cooper and Shepard experiments. Two mind's eye transformation groups will use transformation of the location of the mind's eye as in the Weber and Mankin experiments. On the basis of an informal data analysis and post-experiment interviews in the Mankin pilot study, it is hypothesized that the image transformation strategy will result in greater speed and accuracy. Further, based on Weber and Mankin's results, the specific operations for both strategies which are closest to the 'default' mental perspective will result in better performance. For simplicity, only two head surfaces were used: the forehead, representing a skin area with a strong default orientation, and the left side of the head, representing a skin area with an inconsistent default orientation. Other head areas could have been chosen but it was hypothesized that the results from these two would generalize to other areas. The purpose of including an area with an inconsistent default orientation was to test if the mind's eye transformations would be equivalent for up/inside and up/outside of the head.

Method

Subjects

Twenty-four male and 24 female undergraduate psychology students at Oklahoma State University were randomly assigned to four experimental groups with an equal number of males and females in each group. All subjects ranged in age from 18-24 years old and were native speakers of the English language. The subjects were given extra credit in their courses in return for participation. An additional five subjects were discarded because their patterns of errors indicated an inability to correctly perform the task.

Procedure

The two image transformation groups (forehead group and left side of the head group) were asked to make rotations of the visual image while keeping the location of the mind's eye stationary. The two mind's eye transformation groups (forehead group and left side group) were asked to make translations of the mind's eye while keeping the image of the letter on the head stationary. Functionally equivalent operations were executed in each of the two transformation strategy conditions. Each of the four operations for each group were numerically coded to insure that all groups received the exact same cueing stimuli. For the image transformation groups, the four numerical cueing codes (1,2,3,4) were defined as: 1. normal (mind's eye stationary and located inside the head looking out), 2. mirror image (image rotated in the depth plane so that the mirror image of the original figure as seen from inside the head looking out is seen), 3. upside down (image rotated in the picture plane so that it is upside down in the six o'clock position), 4. mirror + upside down (image flipped in the depth plane so that it appears upside down and backwards). For the mind's eye transformation groups, the four numerical cueing codes (1,2,3,4) were defined as: 1. up/inside (mind's eye inside the head looking out, where the mind's eye is in an upright orientation), 2. up/outside (mind's eye outside the head looking back towards the head, where the mind's eye is in an upright orientation), 3. down/inside (mind's eye inside looking out, where it is in an upside down orientation), 4. down/outside (mind's eye outside looking in, where it is in an upside down orientation).

Presentations on the left side of the head were immediately anterior to the ear. Four stimulus items (p,q,b,d) were traced for each of the four operations. Two complete replications of the 16 unique combinations of letter and operation were given to each subject. Each replication contained uniquely randomized presentations of the 16 combinations and immediately followed each other. In summary, the design consisted of 2 transformation strategies (image, mind's eye) x 2 head surfaces (forehead, left side) x 2 sexes x 4 operations (normal or up/inside, mirror image or up/outside, upside down or down/outside, and mirror down upside down or down/outside) x 4 letters (p,q,b,d) x 2 replications. The transformations, head surfaces, and sex variables were between-subjects; the other variables were within-subjects.

Subjects were first instructed about the details of the experiment, including the identities and meanings of the cueing codes, the strategy for transforming the image or the mind's eye, and other aspects of the procedure. A one-foot square glass plate with a printed lower case letter (p) was used to explain how different image rotations or translations of the mind's eye could result in the perception of other letters (q,b,d). Subjects in the mind's eye condition were instructed as to how they should translate the mind's eye by witnessing the drawing of a human unisex figure placed in different orientations to the glass plate. The subjects were cautioned to respond as quickly but as accurately as possible, with the emphasis upon maintaining clear accurate visual images of the stimuli. The instructions for the image transformation strategy groups were similar to those for the mind's eye transformation strategy groups except for the obvious differences in explaining the appropriate transformation strategy. Appendix C gives the verbatim instructions for both strategies.

Two series of practice trials were given to each subject during the instructional period. The first series helped subjects to memorize the numerical cueing codes. The second series was to insure that people were thoroughly familiar with the task, with subjects experiencing each of the four operations. Presentation order for each set of practice trials was composed of a unique random combination of operation and letter. If any subject was unable to comprehend or perform the task as indicated during practice, he or she was not considered in the experiment.

After receiving instructions and training, subjects closed their eyes for the entire replication. The male experimenter simultaneously traced a letter on the appropriate head area and verbally gave one of the numerical cues for the required operation. The clock was started at the same time that the numerical cue was given. The time for simultaneously tracing the figure and verbally presenting the numerical cueing code was approximately 1.5 seconds. Subjects pressed a button control connected to a millisecond timer which stopped the timer and displayed the reaction time for naming the letter. The subjects were asked to verbally name the letter at exactly the same time as they stopped the clock. The experimenter then recorded the subject's reaction time and verbal response in order to score speed and accuracy. Figure 1 graphically displays the time course for a single trial.

Insert Figure 1 about here

At the end of the two 16 trial replications, all subjects were asked a short series of questions. The post-experiment questions were:

(1) What percent of the time did you accidentally open your eyes during the experiment? (2) Which of the ways of changing the image (your perspective) seemed most difficult? (3) What did you see in your mind as you were trying to decide which letter it was? (4) What do you think the purpose of this experiment was? These questions were used primarily to verify if subjects correctly followed the instructions and used the transformation strategy appropriate to their group.

Stimuli

Stimuli were the four lower-case letters p,q,b,d. They were firmly traced with the experimenter's finger on a 3 x 6 cm. area each on the subject's skin. All letters were traced starting with the stem of the letter and proceeding to the circle. The writing time was about 1.5 seconds.

Results

The most important result is indicated by the significant interaction between the two transformation strategies and the four operations, F (3,120) = 11.77, $p < .001$. Figure 2 displays the means, standard deviations and percentage of errors for this interaction.

Insert Figure 2 about here

The image strategy subjects responded in a gradually slower fashion across the four operations (normal mean = 1.082 seconds, mirror image = 2.004, upside down = 2.739, and mirror + upside down = 2.969). For Newman-Keuls' multiple range tests, critical differences for significance are reported. The Newman-Keuls' test revealed that none of these four operations is significantly different from its adjacent operation. Overall, though, the gradually increasing function of mean reaction times across these four operations is significant with differences exceeding the value, C.diff.4 = 1.255, $p < .05$. The mind's eye strategy subjects, on the other hand, responded in a dramatically slower fashion across the four equivalent operations (up/inside mean = 1.851 seconds, up/outside = 3.908, down/inside = 6.271, and down/outside = 7.507). The Newman-Keuls' test between this set of means revealed that each of the four operations is significantly slower than the preceding operation (C.diff.2 = .955, $p < .05$). The default operations for each transformation strategy (normal for the image strategy and up/inside or up/outside for the mind's eye strategy) did not differ from each other with respect to reaction time (C.diff.2 = 1.219).

The percentages of errors for the transformation by operation interaction are given in the bottom right corner of Figure 2. For each data point there was a total of 192 errors possible. As shown, the range of errors is from 0% in the normal operation in the image transfromation strategy to 39% in the down/outside operation in the mind's eye strategy. Error rates were positively correlated with reaction times over both transformations with $r = .95$, $p < .001$. The patterns of errors showed that the majority of mistakes occurred when subjects responded by naming the mirror image of the correct letter. This was especially true for the mind's eye transformation group where 84% of all errors were of this type. Among the image transformation subjects, this pattern of responding dropped to 58%.

An analysis of variance was conducted on correct reaction time scores with 2 transformation strategies (image and mind's eye) x 2 head areas (forehead and left side) x 2 sexes as the between subjects variables. The within-subjects variables were 4 operations (normal or up/inside, mirror image or up/outside, upside down or down/inside, and mirror + upside down or down/outside) x 2 replications. The analyses were performed on correct responses only. Four stimuli were presented in each of the eight within-subjects conditions. Because of errors on one or more of these four stimuli, the mean response time across the eight cells for each subject were used in the analyses.

A summary of the analysis of variance is given in Appendix D. As expected, the image transformation groups responded significantly faster than the mind's eye transformation groups, $F\ (1,40) = 38.61$, $p < .001$. The mean for the image transformation = 2.185 seconds and the mean for the mind's eye transformation = 4.884 seconds.

A significant effect occurred between the four pairs of functionally equivalent operations, $F\ (3,120) = 49.01$, $p < .001$. Even though the two transformation strategies used structurally dissimilar processes in performing the operations, the analysis of variance indicated that across both transformations the operations were increasingly time consuming, in the order normal or up/inside, mirror image or up/outside, upside down or down/inside, and mirror + upside down or down/outside. The respective means were 1.439, 2.956, 4.505 and 5.238 seconds. A Newman-Keuls' test showed that these pairwise means were significantly different from one another (C.diff.2 = .675, $p < .05$).

Replication 1 of the experiment revealed a manner of responding which was significantly slower than replication 2 (mean for replication 1 = 3.715, mean for replication 2 = 3.354), $F\ (1,40) = 6.61$, $p < .05$. There was a significant sex x replication interaction with, $F\ (1,40) =$

6.38, $p < .05$. Males in replication 1 had a mean time of 3.667 seconds. In replication 2 their times dropped to 2.953 seconds. The Newman-Keuls' test indicated that this drop in times was significant (C.diff.2 = .40, $p < .05$). Females on the other hand did not differ in their reaction times across the two replications (replication 1 mean = 3.763, replication 2 mean = 3.756). Finally, a significant effect was observed on the interaction between transformation strategy, sex, and replication with, F (1,40) = 4.61, $p < .05$. This interaction indicated that males in the mind's eye transformation groups responded significantly faster across replications with replication 1 mean = 5.133 seconds and replication 2 mean = 4.145 seconds (C.diff.3 = .681, $p < .05$). Males in the image transformation groups responded about equally as fast across replications. Female response patterns remained essentially unchanged across the two transformations and replications. In sum, the significant replication effect can be attributed primarily to the increased speed of male subjects in the mind's eye transformation groups.

Finally, the analysis of variance indicated that two additional interactions were significant. First, an effect was calculated on the head surface x replication x operation interaction with, F (3,120) = 4.17, $p < .01$. A preliminary analysis of the means resulted in the conclusion that the effect was due to chance fluctuations in the data. These fluctuations occurred predominately on two of the four operations in each replication (upside down and down/inside; and mirror + upside down and down/outside). Second, the transformation x head surface x replication x operation interaction was significant with, F (3,120) = 3.08, $p < .05$. Again, no interpretable results could be determined in an exploratory analysis of the means. The mind's eye transformation on the forehead and left side of the head showed unsystematic fluctuations of reaction times on the down/inside and down/outside opeations.

The post-experiment questionnaire showed that 100% of the subjects reported that they kept their eyes closed throughout the experiment. A small percentage of subjects did claim that this was difficult to do. In terms of the relative difficulty of performing the four operations, 44% of the image transformation subjects reported that the mirror + upside down operation was the hardest. The second most difficult operation was upside down (33%). The mirror image operation was thought to be relatively easy (13%), while the normal, or default, perspective was easiest (4%). For the mind's eye transformation, the most difficult operation was down/outside (60%). The remaining 40% of the subjects stated that the down/inside operation was hardest.

An important post-experiment question dealt with what the subjects 'saw' in their imagination while trying to decide which letter was correct. The vast majority of the image strategy subjects reported that they saw the letters rotating, flipping, or moving. Some of these subjects stated that the letter appeared to be on a glass plate or blackboard. The mind's eye strategy subjects generally claimed that they would mentally spin, rotate, or move around to achieve the correct perspective, then look at the letter from that perspective. Approximately 10% of the mind's eye subjects claimed that when they mentally stood on their heads, they would frequently lose sight of the letter. Others claimed that when they mentally moved around, the letters would unintentionally move or turn.

Although all subjects claimed that they adhered to the instructed method for transforming images and the mind's eye, the post-experiment interview indicated that for the mind's eye subjects this may not have been entirely true. Fifty percent of the males in the mind's eye groups related that they at times used alternative strategies when trying to transform the mind's eye. Typically these alternative strategies were of two types: when moving the mind's eye to the down/outside position, some males simply moved as if they were "peeking over a wall at the letter". Another strategy for the down/outside position was to move the mind's eye to the up/outside position, then rotate the letter so that a functionally equivalent answer to down/outside was obtained. Only 25% of the mind's eye transformation females reported using alternative strategies at times but no typical instructional deviations could be determined. In all, the percent of deviation from instructions for any one subject did not necessitate that they be replaced. These deviations probably led to making the transformation differences obtained more conservative, because they focused on making the difficult operations easier.

As to the purpose of the experiment, most subjects thought it was designed to study the speed of perception or to study how we see and visualize things.

Discussion

The findings of the present study verified that image transformation with the mind's eye fixed in a stationary position is more efficient and effective than transformations where the image is fixed and the mind's eye moves. These results support the pilot data which suggested that people at times prefer to transform the image rather than the location of the mind's eye. This is not surprising when one considers the complexity of mind's eye transformations. Apparently translating the mind's eye requires at least two parallel processes: attending to the coordinate system through which the mind's eye is moving, and continuing to refresh the target image. Jonides (1980) documented a high cost of shifting attentional resources on images. Therefore, the mind's eye strategy in the present experiment seems to require parallel allocation of resources between attention shifts and the fixed image of the stimulus.

These results may shed some light on cognitive processes responsible for the results of the Kolers and Perkins (1969a, 1969b) letter identification task. Kolers and Perkins found increasing reaction times and error rates for normal, upside down, mirror image, and mirror + upside down transformations of letters, respectively. Their results for the upside down and mirror image transformations were similar to the same transformations in the present image strategy condition. That is, there were no appreciable differences between these two transformations. In the present experiment, the mind's eye transformation resulted in significant differences between operations which are functionally equivalent to the upside down and mirror image operations. This suggests that subjects in the Kolers and Perkins study were using an image transformation strategy for the upside down and mirror image operations. The 'inverted' or mirror + upside down operation in the Kolers and Perkins study showed response patterns which suggest that subjects were using a mind's eye, or combination image and mind's eye, transformation strategy. That is, responses for the inverted operation were significantly longer and less accurate than both the upside down and the mirror image operations.

The interaction between transformation strategy and type of operation suggests that the mind's eye transformation is more sensitive to increased cognitive loads than is image transformation. As the mind's eye operations departed from the default positions the speed and accuracy with which visual images could be manipulated deteriorated quite rapidly. Image transformation, on the other hand, remained relatively stable through various operations. It appears then that the structural processes associated with image transformations as opposed to mind's eye transformations are not disrupted as much by increased cognitive load. It is unclear though whether the cognitive load created by the four operations in the image transformation strategy can be equated with the load created by the four operations in the mind's eye transformation strategy. Finally, as expected, the fastest operations for both the image transformation and the mind's eye transformation were the normal and up/inside operations respectively. These operations actually required no movement in the imagery system at all. It is thought that the mind's eye transformation strategy may be nearly as effective a method as image transformation as long as the required movements of the mind's eye are along simple, well traversed dimensions. For example, the up/outside origin is a very consistent default position for stimuli traced on the top and back of the head (see Weber and Mankin, Note 1). Mind's eye movements along the track from up/inside the head to up/outside on the top and back should be quite fast and accurate.

It is unclear why subjects responded equally well between the two head areas. Weber and Mankin determined that the sides of the head had no consistent default perspective for the mind's eye. That is, people responded with a mixture of up/inside and up/outside orientations to cutaneous tracings. The forehead, on the other hand, possessed a clear default origin. It was expected that for the mind's eye transformation the forehead would show faster reaction times for the up/inside origin than for up/outside, while these two orientations should have had about equal times on the left side of the head. Results showed that the expectations based on default origins of the mind's eye were not confirmed. The most simple interpretation of this finding is that the reaction times measured in this experiment are more sensitive than the frequency measures on which the default results were based. That is, the frequency measures (Weber and Mankin, note 1) indicated a nearly equal distribution of subjects who gave up/inside and up/outside responses to letters drawn on the sides of the head. These frequency measures provided no information on the speed with which responses were made.

Consider now the results from the two replications. Overall, replication 2 showed faster reaction times. This is not surprising when one considers the effects of practice in memorizing cueing codes. What is of interest is the interactions between replication and sex. Males seemed to experience a greater practice effect when moving the mind's eye through difficult operations than did females. Duke (1966) argued that males showed less strict adherence of the mind's eye to default orientations. Allen and Rudy (1970) tested Duke's findings but found no sex differences. The present findings were not interpreted in support for Duke's sex and default adherence idea. Instead, because males performed better on the more complex mind's eye operations, a different set of hypotheses is offered. Hinztman (1979) reported that subjects did benefit from repetition of orientation but found no differences between sexes on simple tasks. The findings in the present study therefore may be explained in at least two ways. First, it is possible that males are more effective than females in performing complex frame of reference shifts in visual imagery. A second explanation is that some males may have developed alternative strategies which facilitated the mind's eye movement whereas females adhered to the instructed transformation. The results of the post-experiment questionnaire do tend to support this second explanation.

Finally, the proportion of errors made in naming letters from different operations increased with reaction times. This result, although contrary to the usual speed/accuracy tradeoff, is probable for at least two reasons. First, it appears that visual images require considerable maintenance (Kosslyn, 1980). The more complex operations in the study may require enough cognitive effort so that routine refreshing of images is impaired. Second, concerning the high error rate for the mind's eye transformation, it is possible that incidental flipping or rotating of the letters occurred along with the translation of the mind's eye. The second account for the patterns of errors has some merit. The percentage of errors which were the mirror image of the correct response was extremely high. This inadvertant mirror imaging could easily occur if subjects experienced difficulty holding images in a fixed position. Furthermore, post-experiment interviews confirmed that some subjects had difficulty holding images in a fixed position while they performed translations of the mind's eye. The hypothesis that the patterns of errors were the result of incidental flipping of images lends support to Hintzman's (Note 2) studies on cognitive maps.

Hintzman contends that difficult rotations of cognitive maps may result in incidental mirror imaging of some parts of the map.

The results of the present study raise an important question. It is apparent that people can either transform an image or transform the orientation of the mind's eye to achieve functionally equivalent perspectives of an imaged object. Are there features of particular images or of tasks involving images which govern whether or not one of these two strategies is generally employed?

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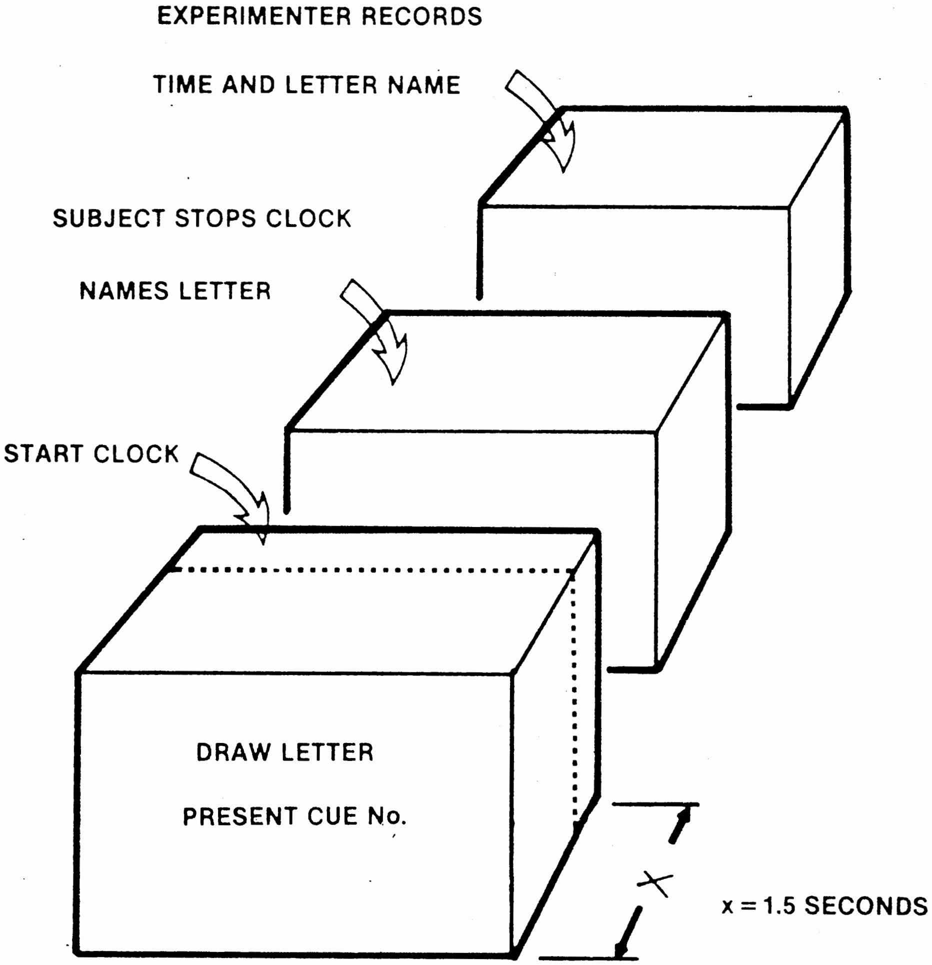
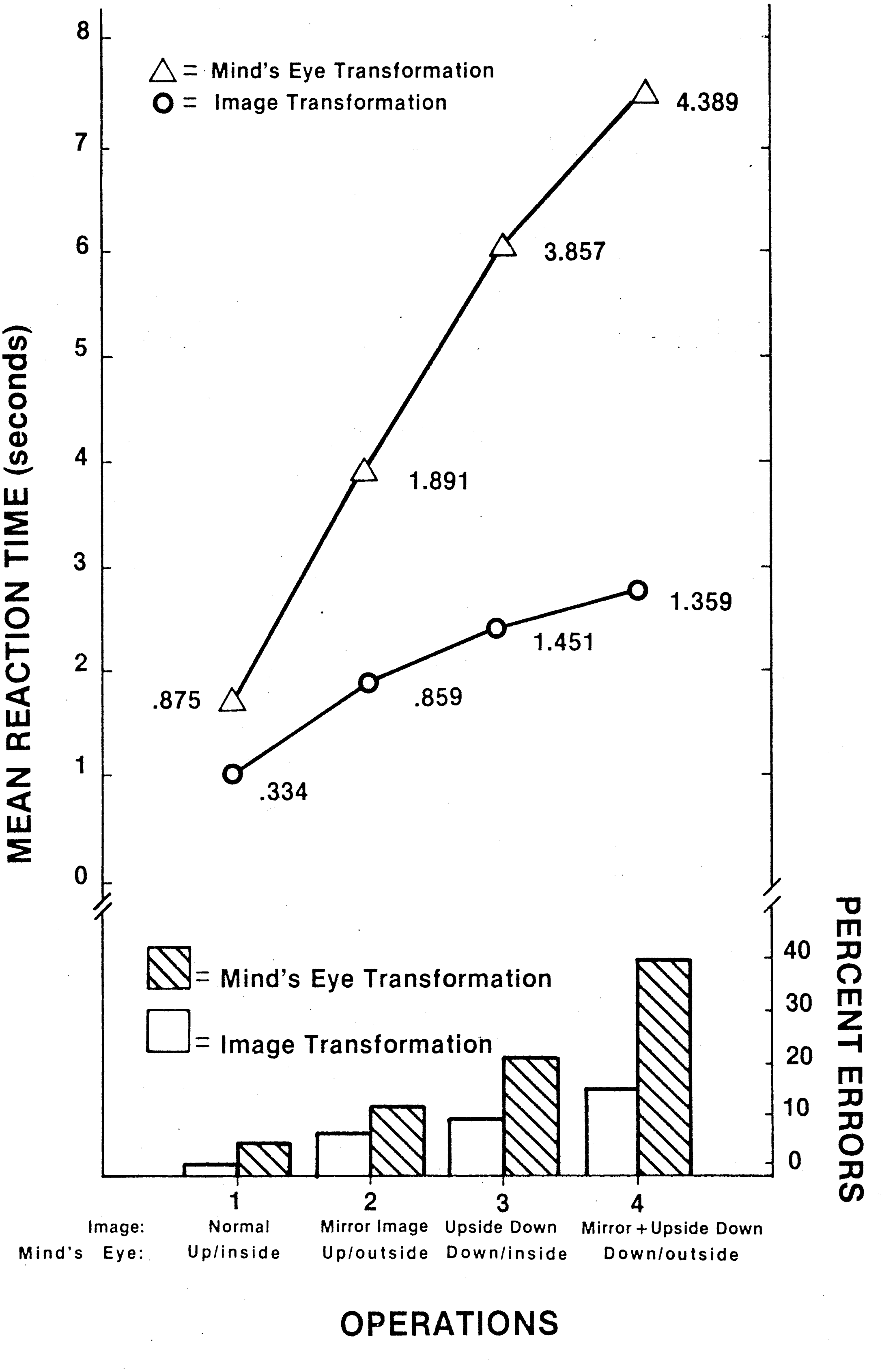
Figure Captions

Figure 1. Time course of a single trial.

Figure 2. Mean reaction times and error percentages for transformation strategies across operations, with standard deviations adjacent to each mean.


EXPERIMENTER RECORDS
TIME AND LETTER NAME
SUBJECT STOPS CLOCK
NAMES LETTER
START CLOCK
DRAW LETTER
PRESENT CUE No.
x
x = 1.5 SECONDS


MEAN REACTION TIME (seconds)
8
7
6
5
4
3
2
1
0
△ = Mind's Eye Transformation
○ = Image Transformation
.875
1.891
3.857
4.389
.334
.859
1.451
1.359
▨ = Mind's Eye Transformation
☐ = Image Transformation
PERCENT ERRORS
40
30
20
10
0
1
2
3
4
Image:
Normal
Mirror Image
Upside Down
Mirror + Upside Down
Mind's Eye:
Up/inside
Up/outside
Down/inside
Down/outside
OPERATIONS

APPENDIXES

APPENDIX A

TABLE OF MEANS - PILOT DATA

Table 1

Mean Reaction Times (msec.) (Mankin and Fiebig Pilot Study)

n = 6

	up/inside	up/outside	down/inside	down/outside
FRONT	397.13	499.94	953.87	1507.7
BACK	573.22	270.91	1056.29	890.05
LEFT	389.18	372.95	764.73	937.63
RIGHT	549.57	809.43	1032.21	1303.42

Instruction Orientation for the Mind's Eye

APPENDIX B

MENTAL IMAGES AND MENTAL MAPS

Introduction

The present experiment compares two fundamentally different methods for making rotations or transformations in spatial imagery. In the first method, transforming the image, the person performs an alteration of the image while the mind's eye remains at a fixed orientation. This behavior is analogous to that of observing a cathode ray tube where the transformations occur in a coordinate space out 'in front' of the mind's eye. Kosslyn (1980, 1981) has elaborated in great detail upon this method of image transformation. In his publications, Kosslyn summarized an enormous amount of research which analyzes such things as the generation of visual images, how we inspect visual images, and transformation of images. In addition, Kosslyn posits a comprehensive theory to account for the findings of this research. Part of this theory is the notion that people utilize a mental screen of definable parameters upon which images are formatted.

A second method for making changes in a person's visual image system occurs when the mind's eye does not remain fixed but seems to move in a three-dimensional coordinate space around a fixed image. This behavior may occur, for example, when a person assumes a 'bird's eye view' of some imagined object or scene. The notion that one can move through different mental points of view is implied in literature that focuses upon cognitive maps (Tolman, 1948) and literature dealing with attention allocation (Jonides, 1980). Implicit in this view is that people are free to allocate attention in spatial images while the image itself remains fixed.

The concept of a 'mind's eye' is best defined as a simile for the interpretive processes that extract information from the image buffer. These interpretive processes behave *as if* they are a disembodied eye that can (a) move around the mental representation of the environment or (b) produce or interpret operations on the image representation.

This appendix will outline differences between the two transformation processes introduced above by discussing and summarizing key research and then placing the findings of that research in a general theoretical context. Before starting, comments on an overall theory of mental images will provide some perspective.

Mental Images as Propositions or Quasi-Pictures

A long-standing debate regarding the nature of mental images remains to some degree unresolved (Pylyshyn, 1981). This debate centers around whether spatial representations of information (images) are analogic or propositional in structure. The following discussion should help dispel some of the arguments against the view that images are not quasi-pictorial analog spatial depictions but rather are epiphenomenal by-products of propositional processing. This second alternative rests upon the argument that images appear to behave as second-order isomorphic spatial presentations simply because people have tacit knowledge of the behavior of real world objects (Pylyshyn, 1981).

The Propositional View

Anderson (1978) outlined the defining terms of the concept of a proposition. He stated that a proposition is abstract, it has a truth value, and it has rules of formation. Abstractness refers to the 'invariance' of a proposition. That is, propositions may be paraphrased across languages. The truth value of a proposition refers to the logical relatedness of it to other propositions. Finally, the rules of formation of a proposition mean that a well-formed proposition adheres to clearly identifiable predicates and arguments. In sum, a proposition is not synonomous with verbal or pictorial representations of information. Rather, it is an encoding system which is unavailable to phenomenological interpretation but which underlies such interpretations.

A group of researchers, particularly Pylyshyn (1973) and Anderson and Bower (1973) hold that images are coded in an abstract propositional format in much the same manner as semantic information. According to this view, images can be diagrammed in an hierachical fashion which depicts the relationships among parts of the image. Dynamic functions such as scanning and rotating images is thought to occur in a sequential, propositional form (cf. Hintzman, Note 2).

Anderson and Bower (1973) argued that image scanning in a sequential manner occurs much like the functioning of a computer program. They state that a proper explanation of image scanning must account for (a) the symbol structure that represents spatial information, and (b) the executive processes that operate upon that information. The computer program metaphor, which Anderson and Bower adopted to account for linguistic systems, was used to argue for the similarity between visual images and language. In other words, images as quasi-pictorial analogs of perceptions have no intrinsic structural properties which make them stand apart from abstract propositional encodings.

Anderson and Bower used results from an experiment by Wiseman and Neisser (Note 3) to support this claim. Wiseman and Neisser showed subjects Mooney pictures (relatively ambiguous spots of ink which were obtained by deleting parts of natural objects). Subjects were asked to construct the concealed objects from the parts on the cards. In addition to this set of cards, subjects were also shown some previously shown and some distractor pictures. For each of the test cards the subject was asked (a) to 'see' some object in the pattern and say what he saw, and (b) to judge whether or not he had seen this exact stimulus pattern before. Results indicated that subjects could not remember seeing patterns which they had previously seen before <u>unless</u> they were able to interpret those patterns and give them a name. Anderson and Bower used these results to support their claim that people do not remember visual scenes but rather remember interpretations. In other words, images are not stored in memory; only information represented as abstracted, conceptual propositions is stored.

The crucial point of the propositional view of imagery is that people are mistaken when they interpret visual images as something unique in cognition. Rather, the argument states that visual or mental images are not unique either functionally or structurally from a principle representation which is neutral with respect to modality.

The Quasi-Pictorial View

Kosslyn (1973), Shepard (1978), and Paivio (1971) differ from those who hold to a strict propositional view of imagery by offering evidence that images are qualitatively distinct cognitive events. This is not to say that propositional encodings have nothing whatsoever to do with visual images, but only that there is a distinction between surface representations and the deep structure by which those representations are derived.

Kosslyn (1973) addressed the question of whether or not images are subject to the same processing requirements as verbal information. Kosslyn's hypothesis was that if images (surface representations) are qualitatively different from semantic material then subjects who scan visual images of objects will do so at a faster rate than subjects who memorize information about the same objects. Kosslyn thought that subjects who image objects have access to most if not all of the information about the imaged object simultaneously. Subjects who have memorized verbal reports must retrieve information from a sequential search through a propositional network. The image group subjects first familiarized themselves with a series of pictures (boat, airplane, lighthouse, etc.). After they had memorized the objects and claimed they could see mental pictures of them, they were asked if certain properties existed on the imaged objects. Half the time the test item was present, and half the time it was not. Subjects were asked to "look at the image", while focusing on a starting point either at the left or right end of the image, and press one button if they could see the test item and push another button if they could not. Members of the verbal report group (who apparently did not use mental images) were asked to memorize verbal discriptions of the objects. These subjects were first asked to name objects on either the beginning or the end of the description list before receiving a probe word. When the probe word appeared, subjects who had named an object on the tail end of the list were thought to move backwards through the list in order to verify the probe. Subjects who had named an object on the front end of the list were thought to move forewards through the list in order to verify the probe. Results of the experiment showed that, for the image group, more time was taken to "scan" across longer distances. For the verbal group, the effects of distance were much more pronounced. Also, it was equally easy for image group subjects to scan from right to left as it was to scan left to right. The verbal group subjects, on the other hand, found it much more time-consuming to scan right to left than left to right. The results from this study, supported by results from a later series of similar experiments on image scanning (see Kosslyn, 1980, chapter 3), suggest that image scanning involves processes which are different from those used while working with verbal descriptions. Verbal descriptions appear to be controlled by propositional formatting structures like links, nodes, and the like (Anderson and Bower, 1973), whereas images may be controlled by the formatting structures of a visual buffer system.

It is apparent that a visual or mental image, once it has been constructed, has at least some unique properties and functions. Those who argue for a propositional structure of imagery focus primarily upon the construction process or the deep representational structure. Researchers like Kosslyn, who argue that the surface representation is dissimilar from the deep structure, openly admit that some processing of deeper, possibly non-spatial information is involved in the imagery system. The difference is that quasi-pictorialists are convinced of the unique functional and structural properties of the surface representation.

Mental Images

Much can be said about the nature of mental images. The purpose here is not to summarize research on all aspects of images, but only to focus upon the image after it has undergone construction. This discussion will be limited to the subjectively experienced image which is assumed to be a distinct class of cognitive phenomena. The purpose here is to establish an argument that mental images are structurally different, albeit related, to mental maps.

Pylyshyn (1981) attacked the theory that images are analog spatial phenomena by comparing the behavior of images to laws of physics. He stated that if images were pictures in the mind (first-order isomorphisms), they would have actual distances. The argument proceeds that if actual distances existed, then image rotation would follow the law:

$$T = D/S \; . \qquad (1)$$

In this equation, T = real time, D = real distance, and S = real speed. Because Kosslyn, et al. do not speak in terms of real distance, but of representational distance, Pylyshyn concluded that images are therefore not analogic with real phenomena. Comments on the weakness of this argument seem inappropriate. Let it be understood that equation 1 has never had any applicability to the real world as it fails to account for friction, slope, weight, etc.

The argument that images must correspond exactly to external events and things has been termed the "picture-in-the-mind" view. This, of course, has been explicitly denied as reasonable by Kosslyn (1980).

Instead, many publications (Kosslyn & Shwartz, 1977; Paivio, 1971; Shepard et al., 1973, 1975) posit that images represent spatial information by way of a second-order isomorphism. Because the surface representation does not preserve actual size, shape, orientation, and location information, it is also referred to as "quasi-pictorial". This view holds that images which occur in a surface representation are distinct from underlying encodings which lie in a deep representation.

A quasi-pictorial spatial array, or the surface image, contains formatting parameters. These parameters are defined primarily by the visual buffer in which the subjectively experienced image is constructed. The parameters of the visual buffer discussed here will be resolution, boundaries, and fade rate.

Several of Kosslyn's (1975) experiments have focused on the resolution of the visual buffer. The typical experiment asks subjects to image scenes containing various sized animals. When asked questions about the animals, subjects took longer to answer when the images were small rather than large. The results of such studies support the notion that the visual buffer contains a limited resolution. If images or parts of images require a finer 'grain' for depiction than the resolution parameter allows, they will suffer in form and clarity.

Another of Kosslyn's series of experiments dealt with the maximum angle of the mind's eye and the spatial extent of the visual buffer (see Kosslyn, 1980, Chapter 3). The general method of these studies was as follows. People shut their eyes and formed a visual image of an object which was to be perceived as if it were at a distance. They then imagined that they were moving closer to the object until the image overflowed the image space. At this point, subjects estimated the distance from themselves to the imagined object pretending as if the object were real. These subjective measures of size and proximity were finally used to estimate the angle of the mind's eye and thus the size of the visual buffer. Although Kosslyn's method of determining the boundaries of the visual buffer is subject to some criticisms (Weber, 1981; Hintzman, Note 4), it demonstrates two important points: images are constructed in a visual buffer, and this two-dimensional display area is a functional formatting medium with unique properties.

The concept of a visual buffer upon which images are mapped is also supported by studies on the fade rate of images. There appears to be a limit on the number of parts that can be imaged at one time. Because of this limit, when people image a relatively complex scene, some parts appear to fade as the image is retained while other parts are either inserted or re-inserted into the image over time.

Kosslyn (1975) reported an experiment which addressed this issue. People were to image animals next to an imaginary matrix. The matrix contained either four or sixteen cells. Subjects were asked to look for a part of the animal and if it was not present, to place it at the correct location. They were then asked to judge whether or not the test part fit on the image. Results showed that reaction times were higher for the sixteen cell matrix condition. These findings were used to support the claim that as images increase in complexity, more time is required to keep the image clearly mapped in the visual buffer. The assumption Kosslyn (1980) makes is that scanning and decision time in this type of task is a function of the time it takes to refresh parts of an image that have faded.

The accounts given by Kosslyn on resolution, boundaries, and fade rate of images are used here to provide a straightforward argument for the existence of a visual buffer. The buffer is the media through which formatted spatial displays are projected. A mind's eye witnesses (interprets) the spatial displays as if they occurred on the two-dimensional screen of a CRT (Kosslyn, 1980). This metaphor of the CRT is a pivotal part of Kosslyn's theory and provides the grounds for arguing that surfacing representations are different from deep representations. This metaphor is supported by research and although in part abandoned, gave rise to a more detailed simulation of the imagery system.

The notion of images as second-order isomorphic displays on a visual buffer is crucial to studies of image transformation. In the present work it is assumed that images of stimuli are mapped out according to the formatting principles discussed above. Especially in the image transformation condition of the present study, it is assumed that a mind's eye, located in a fixed position, interprets the analogic rotation of images on a two-dimensional visual buffer. This view is not inconsistent with Kosslyn's who maintains that once a surface image is present, other processes, such as rotations, may be used (cf. Weber, 1981).

Mental Maps

Underlying the notion of adaptive behavior is the idea that our spatial ability is dependent upon possession of a cognitive map of our environment. Downs and Stea (1973) suggested that a cognitive map is a product of acquiring, interpreting, and storing information received from the environment. This section of Appendix B is concerned with the structure of cognitive maps, and their possible relation to mental images.

Trowbridge (1913) studied why people are apt to get lost in unfamiliar places. His speculations led him to believe that people are "ego-centric" with respect to orientation. In other words, people orient themselves primarily by means of a learned abstract coordinate system where dimensions are defined by compass points. Ego-centric orientation is always north/south and east/west in direction. Trowbridge asserts that when a person's body changes direction, a mental image or representation of the true compass dimensions is retained and used to maintain orientation. He called this stored information an "imaginary map". A test of a group of subjects who had imaginary maps revealed higher consistency in the ability to correctly orient themselves to true compass directions than subjects who had their cognitive maps disturbed. In other words, Trowbridge's subjects must have carried with them a mental spatial representation of the environment, and were able to use that representation of the environment to solve orientation problems.

In a series of maze running experiments, Tolman (1948) argued that knowledge of the spatial environment is not simply the product of one-to-one connections between stimuli and responses. Instead, he argued that this knowledge is derived from cognitive processing of stimuli and that the processed information is formatted into a cognitive map of the environment. To support this contention, Tolman related the story of one of Lashley's rats. This rat, after having learned an alley maze, pushed back the cover near the starting box and took a short-cut across to the food box. Tolman suggested that incidents such as Lashley's and experiments along the same vein provide strong support for the idea that wide spatial maps contain more than specifically learned route information and that these maps are available for problem solving.

An experiment by Attneave and Farrar (1977) has very direct bearing upon the question of whether or not cognitive maps involve mental imagery. In addition, the utility of the concept of a mind's eye is introduced. Attneave and Farrar were interested in questions concerning the nature of our internal representation of the environment. Specifically, they wondered how people accurately maintain the status of objects that are outside the angular bounds of our visual system. Subjects in the experiment were individually exposed to a shelf holding seven objects (a pipe, a duck, a pencil, etc.). After studying these objects for some time, they were seated in a chair with their backs turned to the objects. One third of the subjects were to visualize the objects in front of them as if they were still looking at them. The second one-third of the subjects were to imagine the objects in their real positions behind them. The final third of the subjects were controls who sat facing the objects although an opaque curtain prevented their full view. All subjects were asked questions concerning the spatial arrangement of the objects. Results indicated that the three groups did not differe significantly. This result was attributed to large variances between subjects. Of primary interest are the results from the post-experiment questionnaire. All of the subjects who were to visualize the objects as if they were in front of them reported using a visual image to do so. The reports of the subjects who were to visualize the objects behind them were more inconsistent. One strategy was to mentally move all of the objects _over the head_ so that a mirror image of the array was seen. Other subjects reported that they felt they had eyes in the back of their heads. These subjective results call to light the facility with which visual images of spatial environmental relations can be rotated and transformed. More importantly, the authors acknowledge the phenomenon of the rotation of the mind's eye in cognitive mapping tasks.

The phenomenon of movement of the mind's eye is the primary concern of Jonides (1980). Jonides was interested specifically in visual attention-shifting processes when the physical eye remained stationary. It was hypothesized that a sequential allocation model would account for shorter reaction times for subjects to locate targets as the target locations had a higher probability of being found. A forced-choice task measuring a cost-benefit effect was used to test the feasibility of an all-or-none resource allocation model of attention shifts. The experimental task required subjects to sit in a darkened room and examine briefly a string of eight letters. Subjects were to determine whether an upper case letter L or R was in the string. In the 'valid cue' trials an arrow pointer preceeded the display and correctly cued the location of the letter. On 'invalid cue' trials the pointer was misleading and indicated the position of a non-target letter. 'Neutral cue' trials had a diamond shaped pointer which was uninformative. Results indicated that valid cue trials were both faster and more accurate than the invalid cue trials. As the percentage of valid cues in the total set of stimulus presentations decreased, the benefit derived from attending to valid cues decreased. At the same time, the cost of attending to invalid cues decreased. These decreases in costs and benefits occurred linearly over linear decreases in the percentage of valid cues in the set. It was therefore concluded that the all-or-none model of resource allocation cannot be supported. In its place, Jonides offered a model of the mind's eye movement which contains parallel division of resources to parts of an array. He acknowledged that further tests are required which will distinguish between (a) whether division of resources is to all parts simultaneously, or (b) whether the benefits of cued locations is due to subjects mixing simultaneous and parallel allocation of resources.

An important aspect of Jonides work on the movement of the mind's eye is in the connection between attentional resource allocation and cognitive maps. Cognitive maps apparently may be represented as spatial information in a visual buffer; that buffer includes a representation of space behind the head (Attneave and Farrar, 1977) as well as in front (see Kosslyn, et al.). Further, as Jonides indicated, shifts of attention may occur independent of eye movement. Consequently, movement of the mind's eye relative to a three-dimensional coordinate space becomes a plausible process in quasi-pictorial mental images of the environment.

Summary and Conclusion

Details concerning the structure and function of mental images remain unclear. Even so, in the past few years the clever work of some researchers (Kosslyn, 1975, 1980; Shepard, 1978; Paivio, 1971) has provided some answers. First, an image has been defined as a display or representation of spatial information in which some parallel processing may occur. Second, this display has properties which represent some of the salient features of the actual object or scene that is imaged. Because the representation does not preserve the actual size, complexity, etc. of the object, it is termed a second-order isomorphic representation. Finally, the quasi-pictorial representation, as it has also been termed, may be constructed from propositional, or propositional-like deep representations of information. Nevertheless, the surface image is itself a unique and functional cognitive phenomenon.

The surface image is displayed through a functional formatting medium which contains definable parameters (Kosslyn, 1980). Some of those constants are: limited grain for resolution, limited size of the display area, and limited capacity or holding power. An important feature of this system is that processing of the surface representation normally occurs in a dimensional field out 'in front' of the mind's eye. Rotations of the image, such as those described by Cooper and Shepard (1973), are interpreted by a mind's eye which apparently remains at a fixed lccation.

Structures and functions of mental maps are related to those of visual images. However, in contrast, mental maps are spatial representations of information which do not necessarily adhere to the restrictions of a two-dimensional formatting medium out in front of the mind's eye (Attneave and Farrar, 1977). Rather, cognitive maps are spatial representations which indicate routes, paths, and environmental relationships (Tolman, 1948). Cognitive maps function like mental images in that they display spatial information in such a way that parallel processing may occur. This point is very important. The mind's eye can simultaneously observe the displayed spatial field while it moves to various areas of that field (Jonides, 1981).

The theoretical similarities between mental images and mental maps are important for a number of reasons. (1) The visual buffer posited by Kosslyn et al. (1977) may not always be restricted to a confined area in front of the mind's eye. It may, in some cases, use a 360 degree three-dimensional field for formatting and displaying spatial information. (2) In complex mind's eye movements through a cognitive map, parallel as well as sequential processing of information may occur (Hintzman, 1979). This suggests that a simple analog versus propositional argument on the structure of mental images may be naive. (3) The question arises as to the value of mental image transformation versus mind's eye transformation. Are there situations in which it is more expedient to use one or the other of these strategies to arrive at a functionally equivalent result?

APPENDIX C

INSTRUCTIONS

The instructions for the image transformation groups were as follows:

You will be asked to form visual images of letters that are drawn on different sides of your head and then to change the image in some way.

If I draw a lower case letter q on this glass (1 ft. square glass plate), sitting inside where you are now it looks like a p to you, right? We call this way of looking at the letter, #1. Now if I turn the piece of glass this way (mirror image) what letter do you see? (A q.) We call this way of turning the letter, #2. If I took the letter you see here and rotate it upside down, then what letter do you see? (A d.) We call this way of turning the letter, #3. Finally, if I took this letter and turned it upside down and backwards like this, what letter does it become? (A b.) This way of turning the letter is called, #4.

Now let's go over this once again. (Experimenter repeats the process.)

Now you take this piece of glass with the letter on it. I am going to tell you some of the code numbers and you turn the glass the right way. (The experimenter repeats a number of randomly picked code numbers until he feels that the subject has memorized them.)

This experiment is concerned with how well you can form and then turn a visual image of letters. The letters will be drawn on different sides of your head with my finger. The letters that will be drawn on your skin will be p,q,b, and d. (The experimenter shows the subject these letters printed on a 5x8 white card.) The letters were drawn in the following manner. (The experimenter demonstrates this on the card.

All letters were drawn in one identical movement starting with the stem and ending with the loop.)

I will be drawing these letters on your forehead (left side of your head) (experimenter points to his own forehead or left side of his head). I will ask you to close your eyes, then I will draw a letter on your head. At the same time that I draw the letter, I will tell you a number (1,2,3, or 4). Remember, the number tells you which way to turn your image of the letter. After I draw the letter and tell you the number, you turn your visual image of the letter and tell me what letter it looks like from its new position. Push this button at exactly the same time that you tell me the name of the letter. Do this as fast and as accurately as you can. Remember, this experiment is concerned with visual images, so please take as long a time as you need to keep a clear visual image of the letter. If you find it difficult to form the images and turn the letters, please let me know.

Now let's try a few practice trials. Ask me any questions you wish. Ready? Close your eyes.

The instructions for the <u>mind's eye transformation</u> groups were as follows:

This experiment is concerned with visual images. You will be asked to form visual images of letters that are drawn on different sides of your head and then to look at those images from different perspectives.

I want you to pretend that this figure is you and that this piece of glass is the outside of your skin. (The experimenter shows the subject a 5x7 white card on which is drawn a human unisex figure.) If I draw this lower case letter <u>q</u> on the glass, then with your head up and standing inside like this what letter would the figure see? (A p.) Try to mentally move your body to the same orientation as the figure. We call this way of looking at the letter, #1. Now if I drew the same letter on the glass, and you kept that letter in this position but you moved your body outside where the figure now is, with your head up, what letter would you see? Try to see it from the figure's viewpoint. (A q.) We call this way of looking at the letter, #2. If I drew the letter you see here and you were inside and upside down like this (demonstrate with the figure), what letter would you see? (A d.) We call this way of looking at the letter, #3. Finally, if I drew this same letter but you were outside where the figure is and you were upside down, what letter would you see? (A b.) This way of looking at the letter is called, #4.

Now you take this figure. I am going to tell you some of the code numbers and you position the figure so that it is looking at the letters the correct way. At the same time, mentally take the perspective of the figure yourself. (The experimenter repeats a number of randomly picked rotation code numbers until he feels that the subject has memorized them.)

This experiment is concerned with how well you can move yourself mentally around a visual image of a letter that is fixed in one place (same as previous instructions)...Remember, the number tells you which way you are supposed to imagine yourself moving. After I draw the letter and tell you the number, you imagine yourself moving to the right position and tell me what letter it looks like from your new position. Push this button at exactly the same time that you tell me the name of the letter. Do this as fast and as accurately as you can. Remember, this experiment is concerned with visual images, so please take as long a time as you need to keep a clear visual image of the letter as you move. If you find it difficult to form the images and move yourself around, please let me know.

Now let's try a few practice trials. Ask me any questions you wish. Ready? Close your eyes.

APPENDIX D

SUMMARY - ANALYSIS OF VARIANCE

Table 2

Analysis of Variance Summary Table

Source	df	MS	F	P < F
Transformation Strategy (S)	1	699.41	38.61	.001
Head Area (H)	1	26.66	1.47	
S x H	1	0.04	0.00	
Sex (G)	1	19.39	1.07	
S x G	1	0.16	1.01	
H x G	1	33.20	1.83	
S x H x G	1	18.16	1.00	
Error 1 Subjects (S H G)	40	18.11		
<u>Within Subjects</u>				
Replications (R)	1	12.48	6.61	.05
S x R	1	0.08	0.04	
H x R	1	0.006	0.00	
S x H x R	1	0.11	0.06	
G x R	1	12.03	6.38	.05
S x G x R	1	8.70	4.61	.05
H x G x R	1	6.61	3.50	
S x H x G x R	1	2.67	1.41	
Error 2 R x Subjects (S H G)	40	1.89		

Table 2 (Continued)

Source	df	MS	F	P < F
Operation (O)	3	274.15	49.07	.001
S x D	3	65.78	11.77	.001
H x D	3	8.44	1.51	
S x H x D	3	1.45	0.26	
G x D	3	1.05	0.19	
S x G x D	3	0.26	0.05	
H x G x D	3	12.25	2.19	
S x H x G x D	3	7.53	1.35	
Error 3				
D x Subjects (S H G)	120	5.59		
R x D	3	4.09	2.07	
S x R x D	3	2.55	1.29	
H x R x D	3	8.23	4.17	.01
S x H x R x D	3	6.07	3.08	.05
G x R x D	3	4.44	2.25	
S x G x R x D	3	2.51	1.27	
H x G x R x D	3	2.94	1.49	
S x H x G x R x D	3	0.34	0.17	
Error 4				
R x D x Subjects (S H G)	120	1.97		

2

VITA

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