VISUAL SEARCH IN A DYNAMIC FIELD

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CHAPTER I

INTRODUCTION AND SURVEY OF THE LITERATURE

The present paper is concerned with the study of variables affecting visual search of a moving field of letters.

The ability to scan, search, and extract the desired or required information from the environment cannot be visually realized unless the individual has the capacity to discriminate visual patterns of stimulation in a dynamic environment. This is to say, the ability to discriminate forms quickly and accurately has obvious significance for the individual's moment-by-moment responding to continual changes in a dynamic environment.

In most psychological research this ability has usually been studied under the rubric of visual search behavior. These visual search tasks may be generally described as utilizing multiple stimuli from which the S's[1] must locate or identify a particular stimulus or a particular set of stimuli as dictated by E.

The experimental study of visual search behavior can be justified by the predominate role it plays in various occupational situations. Some examples: (1) An industrial manufacturing application would be found in the quality control procedures utilized to visually detect imperfections in a given product. (2) A military application of this

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[1]In this dissertation the letter "S" refers to the experimental subject who is undergoing testing and "E" refers to the experimenter who is conducting the study.

skill is required in aerial reconnaissance in detecting enemy targets. (3) An important medical application is the visual search behavior necessary to conduct a microscopic examination of a specimen for diagnostic purposes.

A visual search in the context of this paper is defined as the process of a search for a visual form or stimulus, while ignoring a moving and potentially distracting or irrelevant background context.

The tasks usually employed in laboratory studies require the _S_s to conduct a discrete search for a predetermined form or target (Underwood, 1966). For example, a letter is placed in an array of more or less similar letters, and upon identification of the target letter; the _S_ is required to make an appropriate response. Various types of stimulus materials have been used in visual search tasks. However, a greater number of studies have employed letters as stimulus material. These studies have typically exposed letter strings for short durations by tachistoscopic devices, and during the exposure of the stimulus required the _S_s to conduct a visual search of the material. Two possible letter strings are shown in Figure 1.

Other studies (Neisser, 1964) have utilized letters printed in lists. Figure 2 illustrates an abbreviated list of letters that have been used by Neisser in studying scanning processes. The _S_'s experimental task was to scan the list using a directional search technique, ie., from left to right for each line of letters and from top to bottom for the succeeding lines. Even though both of these approaches involve a static display of material, the search task of each of these may be further differentiated on the basis of whether eye movement is required in carrying out the search task.

From an analysis of the literature surveyed, it is possible to

P
K
I
A
(1) B
C
T
G

(2) G T C B A I K P

Figure 1. Sample letter strings used in tachistoscopic displays. In No. 1 the letters are arranged on a vertical plane, and No. 2 the letters are arranged on a horizontal plane.

(1)	(2)
EHYP	ZVMBQL
SWIQ	HSQJMF
UFCJ	ZTJVQR
WBYH	RDQTFM
OGTX	TQVRSX
GWVX	MSRQXV
TWLN	ZHQBTL
XJBU	ZJTQXL
UDXI	LHQVXM
HSFT	FVQHMS
VSCQ	MTSDQL
SDJU	TZDFQB
ZHFK	FLDVZT

Figure 2. Stimulus letter lists as used by Neisser. In list No. 1 the target letter is the letter "K". In list No. 2 the target is the line which does not contain the letter "Q".

classify search tasks not only according to subject matter investigated, but also in terms of the presence or absence of eye movement (fixed or pursuit) and upon the field configuration (fixed or moving). To the writer's knowledge there have been few laboratory studies investigating the effects of field movement in a visual search task (Jenkins, 1954), and it is under this condition that visual search behavior is primarily investigated in this paper. Therefore, the following review of the literature will be discussed, where applicable, according to the following classifications:

1) Field Condition
   a. Static
   b. Dynamic

2) Eye Movement
   a. Fixed
   b. Pursuit

<u>Static Field-Fixed Eye Movement</u>. Tachistoscopic presentation of material can be said to involve a passive type of visual search technique. It characteristically does not involve any eye movement to scan the externally presented material. In fact, this mode of presentation is often utilized to eliminate eye movement as an undesired source of variance. Eye movement has often proved itself to be unpredictable, even when repeated measures are made on the same <u>S</u>s and on the same stimuli. The usual procedures in tachistoscopic studies require the <u>S</u> to visually fixate on a point designated by the <u>E</u>, before exposure of the stimulus is made. Then the display is exposed for a duration that is too short to allow a change in the <u>S</u>'s fixation. Most studies have used exposure times of 100 milliseconds or less to prevent changes in fixation. Studies by Harcum (1966), Crovitz (1965), Winnick and Bruder (1968), Averbach and Coriell (1961), Haber and Hershenson (1965) are

representative studies using this type of static field and fixed eye configuration in their investigative procedures.

The experimental rationale for tachistoscopic presentations and how they are related to normal visual processes in perception is explained on the basis of saccadic eye movement. Woodworth (1950), states that in the normal process of perceiving material, the eyes do not provide a continual input of undistorted retinal images. In normal perception the eye will fixate on one part of the stimulus for a period, and this is interrupted by a rapid shift of fixation to another portion of the stimulus or back to the same point. These shorter periods of shifting are called saccadic movements of which there is no voluntary control. During these brief periods of movement, the retinal image is distorted due to an inadequate exposure time. It is only then, during these longer periods of fixation that the retina is stimulated adequately and can produce a clear image. Therefore, tachistoscopic exposures, shorter than 100 milliseconds, are very analogous to the image produced by these brief presentations on the retina when the eye is motionless. Hence, these tasks utilizing a tachistoscope for visual search study can be thought as incorporating a passive eye movement scanning process with a static display of stimuli. This does not deny that some kind of internalized scanning may also occur.

<u>Static Field-Saccadic Eye Movement.</u> Search tasks involving lists of material to be scanned can be characterized as involving an active scanning process with a static display. Studies by Gibson and Yonas (1966), Neisser and Beller (1965), and Kaplan, Yonas, and Shurcliff (1966), serve as examples. Eye movement responses to the visual stimuli may be classified as "saccadic" when there are rapid changes in the fixation point as required in the above mentioned studies. These studies

used lists of material to be scanned using techniques similar to that involved in normal reading behavior. For the S to process the stimulus material he must move his eyes and shift his fixation point to scan the entire stimulus display. This task is usually accomplished by instructing the S to start at the top of the list and scan downward until he identifies the target stimulus.

There are two other possible variants of an experimental scanning task according to this system of classification. One involves a static scan with a moving display of the stimulus material. The other involves both an active scan and movement of the viewing field. Thus, there is both movement on the part of the S and the stimulus set. The eye movements involved in this situation may be classified as "pursuit movements", Woodworth (1938). In this example not only must the S change his fixation points relative to the physical dimension of the stimulus; he must also "track" the display as it moves through space. A great portion of the individual's daily behavior involves movement; either his own movement or his immediate environment, or commonly a combination of both. Thus, the variable of a moving field was felt to deserve a closer inspection of the part it plays in perception.

Another approach in reviewing the literature on visual search tasks is in terms of the problems investigated and subject matter. The majority of research concerned with visual search tasks have been directed toward problems associated with immediate memory variables and the capacity of immediate (short term) memory itself as it functions in this type task. The typical studies have presented Ss with a variety of stimuli and measured the rate or the number of items correctly reported according to the particular variable under investigation. Such experiments have usually revealed something about memory functions and capacity. Studies concerned with the scanning or search rate and other relevant variables, such as the number of targets, processes of character recognition, etc., have been published by Neisser (1964), Gibson and Yonas (1966), Sternberg (1963, 1966), Sperling (1963), and others.

Another group of studies have been concerned with the visual field and the locus of retinal stimulation variables in scanning behavior. Such studies are represented by the works of Crovitz (1965), Bryden (1966), and Winnick (1968).

Harcum has published extensively in this area and his work can be most generally characterized as a study of visual search behavior as a serial process akin to other processes in serial learning. Harcum's (1966) paper is representative of much of his work and interest in mnemonic factors. In this paper he argues for a similarity between pattern perception and serial learning because of a similar distribution of positive errors in recall.

Crovitz (1965), in a study of visual search behavior investigated the variable of letter spacing, the visual field location of letters in relation to a fixation point, and possible differential effects of binocular and monocular viewing conditions. His results and error patterning again support the bow-shaped error function as commonly obtained in other studies. The three experiments carried out in his paper support the assumption that the relative position within a line of letters is the critical variable controlling the accuracy within the letter span rather than the absolute locus in the visual field relative to a fixation point. He obtained similar shaped error functions with variations in the physical distance between the fixation point and the first element position of the letter string. From these results it may be assumed that regardless of the locale of the fixation point, the distribution of errors among the target positions will remain relatively the same.

It is the opinion of the author, that in the preceeding survey of the literature, many of these studies have confounded their results of positional identification variables and error detection rate with mnemonic factors. It would also appear that the experimental task conditions were more sensitive to encoding and mnemonic factors than to the visual factors connected to the perceptual processing of the particular elements within the stimulus strings.

Statement of the Problem

The primary intent of this dissertation, is to compare target identification processes using a dynamic display of stimulus material presented in various ways which would simulate conditions occurring in everyday life. As stated previously, the writer is unaware of any previous investigation of the effect of movement of displayed material on visual search tasks.

There were five variables experimentally manipulated: level of visual context confusion, direction of stimulus movement, scanning time, speed of stimulus movement, and multiple target positions. Several questions were examined in the three experiments conducted. Some of these include the following: (1) What are the possible effects of limited scanning time intervals and level of visual confusion upon target identification? (2) Do differences in the spatial orientation of the letter strings (e.g., horizontal vs. vertical) produce different error rates in the detection of letter elements within the various target positions of the letter string? (3) Will movement of stimuli in one direction have a different effect on the scanning process than movement in the opposite direction of the stimuli? (4) Will minimizing memory components of the experimental task produce a different distribution of errors over the different target positions than those previously found (Harcum, 1966; Crovitz, 1965; Averbach and Coriell, 1961)?

With reference to the first question posed above, Gibson and Yonas (1966), in a study of the effect of context on search speed found a high negative correlation between the level of visual confusion and search speed. In the three experiments conducted in this thesis two levels of target/background confusion were utilized in conjunction with other variables to investigate possible differences in the overall error rate for each condition and any differences in error patterning of positions within the letter string.

Horizontal and vertical (East-West and North-South viewing fields)[2] string orientation were employed to study possible differences in the scanning process according to stimulus orientation. Brown and Strongman (1966), found that the visual search was faster with horizontally presented material, and in the context of this thesis this result should predict an overall lower error rate in the horizontal orientation of stimuli than that of a vertical orientation, given a fixed viewing time.

The effect of movement and the relative speed of the stimuli upon the scanning process were considered to be important and deserving of experimental study. The rationale for investigating this variable can be found in various target search tasks. For example, a pilot, in attempting to locate a target while airborne, typically perceives his visual field as comprising three directions of movement, and the relative speed of the field being a function of his altitude. Immediately in

[2]In perceptual studies it is common to divide the field of view according to cardinal directions. For example, North and South would indicate a top to bottom or vertical plane as viewed by the subject.

front of him the visual field appears to be moving toward him in a top to bottom, or North to South, direction. Viewing the same terrain from his left, the field has movement in a right to left direction and from his right side the field moves in a left to right direction. In reading printed material, and instances of projecting lists of printed material on movie screens and television screens, the material moves typically from bottom to top or from South to North visual fields. Thus comparing movement in these cardinal directions and their effect upon the scanning process has varied practical implications.

One objective common to the three experiments conducted in this dissertation was to determine if there were differences among the positions within a string of letters in detection accuracy. Several tachistoscopic studies have reported conflicting results in the number of errors of the various target positions within a string of letters and also in the error rates for the positions themselves. Averbach and Coriell (1961), obtained results in which the identification of target letters were more accurate at the center and terminal target positions and poorer in between these positions. Figure 3 is derived from their data. Harcum (1957), and the majority of studies dealing with similar material since Woodworth (1938), have generally reported results which may be characterized by the graph in Figure 4. A comparison of these error curves reflect the conflicting results obtained by Harcum and Averbach and Coriell.

In these studies their findings indicate that the terminal positions are more accurately perceived than are the central positions. Woodworth attributes this bow-shaped curve to masking effects caused by the presence of the adjacent letters. As previously mentioned, Harcum (1967), had proposed that there is a common process operative in the

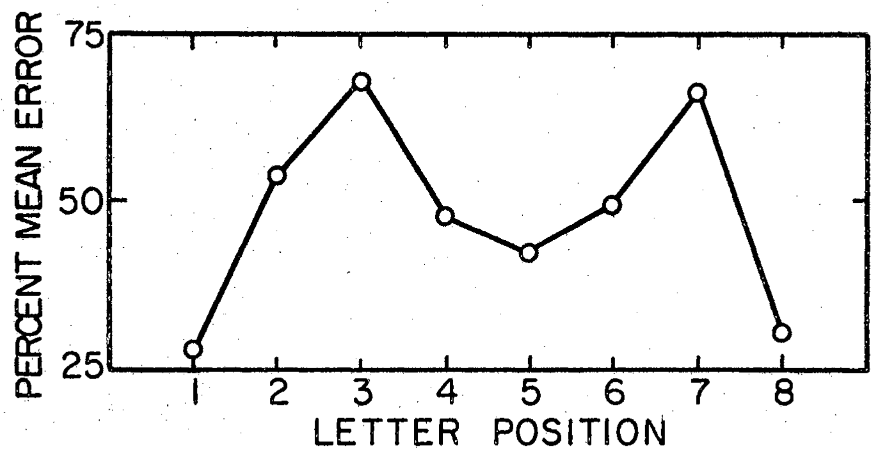

Figure 3. Performance by position in array. Data from Averbach and Coriell (1961).

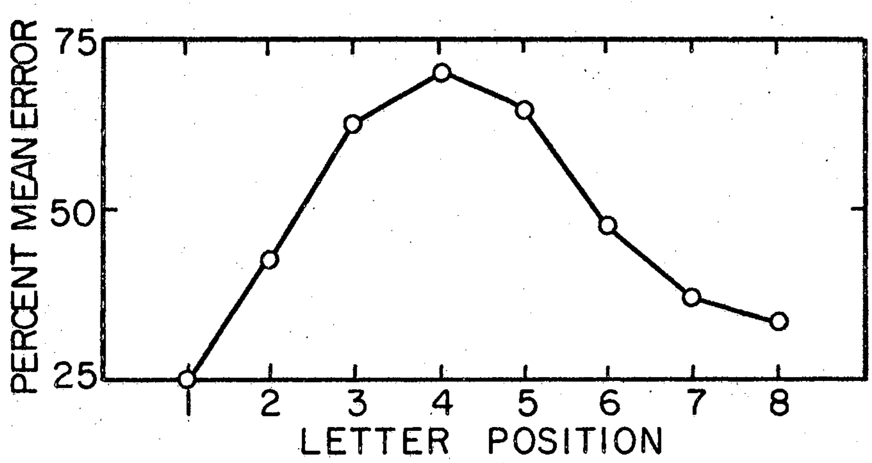

Figure 4. Performance by position in array. Data from Harcum (1967).

distribution of errors within the stimulus string. From the serial position curve as obtained in Figure 4 Harcum advocates that the tachistoscopic perception of spatial patterns as well as serial verbal tasks can be conceptualized as a serial process.

Explanation of the Tests

In order to minimize the effects of serially encoding the stimulus items and the effects of an increased load on mnemonic factors, the Ss were required to make only a partial report relative to a specific letter string. Thus, the Ss were concerned only with the absence or presence and location of a predetermined target letter within a letter string. By adopting this procedure it was hoped that the performance measures obtained would reflect primarily those of visual processes involved in target detection in a scanning task.

Experiments Conducted

Three laboratory experiments were conducted. The first experiment involved a static display of stimulus material, while the remainder utilized a moving display field.

The static display in Experiment I was accomplished by a tachistoscopic projection of letter strings on a viewing screen. The basic purpose of this experiment was to provide information on visual search behavior in a static field as well as affording data which could be equated with those obtained in Experiments II and III in making comparisons of search tasks involving static and dynamic displays of stimuli.

The first experiment was concerned with the following variables and their influence upon scanning behavior: scanning time, stimulus orientation, target/background confusion, monocular versus binocular scanning, and the position of targets within the stimulus string. The principal dependent variable was the S's failure to detect the presence and location of a target letter.

Experiment II was primarily concerned with the effects of the relative velocity of movement upon scanning behavior, holding scanning time constant. The following variables were included: velocity, target/background confusion and error rates among the target positions.

Experiment III investigated the relative effects of the direction of field movement and its effect upon scanning behavior. Variables in this experiment included stimulus orientation, direction of movement, target/background confusion, and target position.

The following chapters describe in detail each of the three experiments and the results obtained.

CHAPTER II

EXPERIMENT I: VISUAL SEARCH IN A STATIC FIELD

This first experiment was designed to fulfill several basic functions. First it was directed toward the study of the following variables in a static field: stimulus orientation, target/background confusability, viewing method, and presentation time. The second function was to provide data on these variables which could be compared with those obtained under a dynamic field condition.

Method

Stimulus Material. Alphabetical capital letters were chosen as stimuli and these were used to make up an eight letter string. There were four sets of letter strings. Each set contained seventy individual letter strings; thirty letter strings contained a target letter, and forty letter strings did not contain a target letter. This particular ratio was selected to study possible effects of changes in target expectancy and the F/A rate; however, no discernable effects were noted. The target letters were randomly positioned within the line which would contain a target letter with the restriction that it never appear in the first or last letter position of the letter string. Thus, in the eight letter string there were six target positions. This restriction on placement of target letters was imposed so that each target position was always bracketed by adjoining letters. This allowed each target position to be equated with the other target positions. The only difference in target positions was in its spatial relationship within the stimulus string. The particular position of the target letter was balanced so that in each set of seventy lines, a target would appear five times in each target position. The remaining seven letters were randomly drawn from a pool of eight other letters, with the restriction that no letter was duplicated in a given line. Each of the individual letter strings was tachistoscopically projected, using 35mm. slides. Four sets of these seventy letter strings were constructed, each representing one of the combinations of target/background confusion and stimulus orientation conditions. The letters were approximately 7/8 inches high, and the string of eight letters subtended 3-4 degrees of visual angle.

Apparatus. The stimulus strings were individually projected upon a white viewing field, by a Kodak Carousel, Model 700 slide projector equipped with a Lafayette tachistoscopic shutter. A second projector was used to create a bright pre-and post-viewing field to reduce possible after images and their disturbing effects. A fixation point was not utilized; however, the stimulus strings were always projected upon a common point. The projector was S controlled, whereby the S could initiate each trial and also determine his own inter-trial interval.

All the trials were run in a small room uniformly illuminated by florescent lighting which remained on throughout the experimental session. The incident light level in the room was approximately 120 foot candles at S's eye level and was within the recommended level of illumination (McCormick, 1964) for visual tasks of this nature. This level tended to minimize the contrast between the viewing screen and the peripheral field of view as experienced by the Ss.

The Ss were seated directly behind the projectors and centered in respect to the stimulus string. The distance from the viewing screen to the S's eyes was held constant at 80" ± 2". At this distance the length of the stimulus string on either the horizontal or vertical axis did not subtend a visual angle of more than 3.5°. The projected size of the stimulus letters were large enough to be clearly seen without any eye strain. The horizontal strings were projected on a plane level to the S's eyes. The vertical strings were projected so that the center of the strings were at eye level. Thus, the entire stimulus was within the angular limits normally attributed to encompass foveal vision.

Experimental Variables. (1) Scanning time: Two lengths of time in which the lines would be scanned were employed. Under condition (T-1) the stimulus strings were exposed for a 350 msec. duration, and for (T-2) the exposure time was 50 msec.

(2) Target/background confusability: The relationship between the target letter and the background letters was measured on the basis of visual confusability. Two levels of visual confusion were derived from a visual confusion letter matrix reported by Kaplan et al. (1966). For the low confusion (LC) condition a single target letter "E", was embedded in a line of seven of the following letters, (V,K,C,I,Y,X,U,D). The high confusion (HC) condition consisted of the target letter "K", and the letters (N,L,F,H,X,Y,R).

(3) Stimulus String Orientation: The letter strings were arrayed on both a horizontal (HS) and a vertical (VS) axis, for each of the two levels of visual confusion.

(4) Viewing Method: All combinations of string orientations and visual confusion were viewed both monocularly and binocularly by the S.

The monocular condition was accomplished by covering the S's nondominate eye with a black surgical eye patch.

Procedure: Ss were tested individually and were assigned to a particular sequence of experimental conditions according to a predetermined randomization schedule. This procedure was carried out to minimize possible biasing caused by sequential and carry over effects.

At the beginning of the experimental session the S was seated comfortably in front of the viewing screen, and instructed in the operation of the equipment controls, and in the manner to record his responses. During this time the E checked the focus of the projected letter strings and made the necessary adjustments to place the projected stimulus line on an approximate eye level with the S. Prior to the beginning of the practice trials each S was read the instructions given in Appendix A.

After instructions were given to the S, the practice trials were begun. After each presentation of a stimulus line the E checked the S as he recorded his response. Each S was given practice trials on both levels of confusion and on both line orientations. The exposure time for these practice trials was 500 msec. The number of practice trials were such that each S reached a criterion of five consecutive identifications of the target letter and its location within the letter string. The range of trials to reach this criterion varied from 50 to 73 trials. All Ss demonstrated a clear understanding of the experimental task and the operation of the equipment before the experimental trials were started. The Ss were then told that the stimulus lines would be exposed for a shorter duration and then the experimental trials began.

Stimulus Presentation and Response Recording: A trial consisted of the following events: 1) the S would look at the viewing screen already illuminated by the pre-and post-field projector. 2) He then would depress a switch to expose the stimulus line. 3) The shutter on the pre- and post-field illuminating projector would close and simultaneously the first projector would display the stimulus string for the proper duration. The presentation of the display was followed by a bright post viewing field. 4) The S would then record his response on the answer sheet and then advance the slide for the next trial. The average time between the trials was approximately four seconds.

Subjects: The Ss employed in this study were students at Oklahoma State University. The Ss served voluntarily and were not compensated for their participation. Two groups of five female and five male Ss with normal vision participated in the experiment. The Ss were randomly assigned to groups, and the sequence of experimental conditions was randomized individually for each S.

Scoring of Responses: The S's responses were scored on the basis of errors committed. The errors were of two basic types. Utilizing signal detection termonology (Swets, 1964), they were classified as either "misses" or "false alarms" (F/A). A response was scored as a "miss" when the S failed to record the presence of a target when it was in a given letter string. A "F/A" was scored when the S attributed the target letter as being in a letter string when, in fact, it was not in the array. A modification of scoring arose from the standard procedures when the S recorded the target letter as occupying a cell position more than one space to either side of its actual location.

A modification from the usual scoring procedures occurred when the S recorded the target letter as being in a cell position more than one space to either side of its actual location. In this instance a given stimulus line would contain both a miss and F/A error. The validity of this procedure came about from results obtained in pilot studies. There were certain procedures in which the S was given trial knowledge of results. Very often they would challenge the accuracy of scoring, and insist that their response was correct. Only after successive presentation of the same line, could they identify the actual target and its position within the letter string. These cases most often occurred when there was a high target/background confusion level.

Experimental Design: The experimental design employed in this study was a randomized split plot factorial design with repeated measures on the last four factors (Kirk, 1968). This involved: two presentation times (50 msec. vs. 350 msec.); two string orientations (horizontal HS vs. vertical VS); two viewing methods (monocular vs. binocular); two confusion levels (high HC vs. low LC); and six target positions (2-7) or eight false alarm positions (F/A 1-8).

Results

The data obtained was such that the S's task performance could be analyzed on the basis of the two error classifications. The first analysis was made on the basis of missed target letters (errors of omission) which will receive major attention in this dissertation. The second analysis of task performance was concerned with F/A (errors of commission).

Performance on the search task as a whole is briefly summarized in Table I in terms of per cent errors. It may be noted that the combined errors produced an error rate of 25.4%, over all trials. There was a failure to detect targets on 29% of the target lines, while 22% of the nontarget lines were reported by the Ss as containing a target letter.

The relative effect of (LC) and (HC) on both type error measurements is demonstrated in the dissimilarity between the type errors made and the confusion level under which they occurred. The missed target error rate under (HC) and (LC) conditions were 48% and 5% respectively. The two levels of visual confusion did not produce a corresponding difference in per cent of F/A errors. The F/A error rate for the (LC) condition was 18% while the error rate under the (HC) condition increased to only 24%.

TABLE I

A SYNOPSIS OF EXPERIMENTAL TASK PERFORMANCE

Total number of stimulus lines presented.	11200
Number of lines containing an error	2850
Percent total error	25.4%
Number of lines containing a target letter.	4800
Number of lines scored as misses.	1430
Percent misses.	29%
Number of lines not containing a target letter.	6400
Number of lines scored as false alarms.	1423
Percent F/A	22%
Number of (LC) target lines	2400
Number of misses.	255
Percent misses (LC)	5%
Number of (HC) target lines	2400
Number of misses.	1175
Percent misses (HC)	48%
Number of (LC) non-target lines	3200
Number of F/A	580
Percent F/A (LC).	18%
Number of (HC) non-target lines	3200
Number of F/A	843
Percent F/A (HC).	24%

<u>Missed Target Errors:</u> As may be seen from Table I the number of missed targets is the most sensitive dependent variable. Figure 5 depicts the percent errors for each of the target positions, while Table II contains the numerical values expressed in terms of average percent error. These values were obtained by summing and averaging errors over the experimental factors of scanning time and viewing method. This graph illustrates the typical curves obtained for each of the conditions contrasting (LC) and (HC) errors. Several statistical findings are apparent from an inspection of this figure.

The first noticeable finding is the similarity between the error curves for the (HS) and (VS) orientations on each level of visual confusion (HC),(LC). Another characteristic of these curves is that there appears to be not only a quantitative, but a qualitative difference of errors between the (LC) and (HC) condition.

Under the (LC) condition, the error rates among the various target positions appear to be relatively equal, with the exception of position number 7. The (HC) condition produced notable differences in error rates, especially when contrasting the central and lateral target positions. Under both (HS) and (VS) conditions the error curves resembled a "modified V" shape curve. The shape of this curve and the associated error rate is opposite that usually reported in the literature by Harcum and others. The usual findings attribute more errors occurring in the central portion of the string rather than the lateral positions.

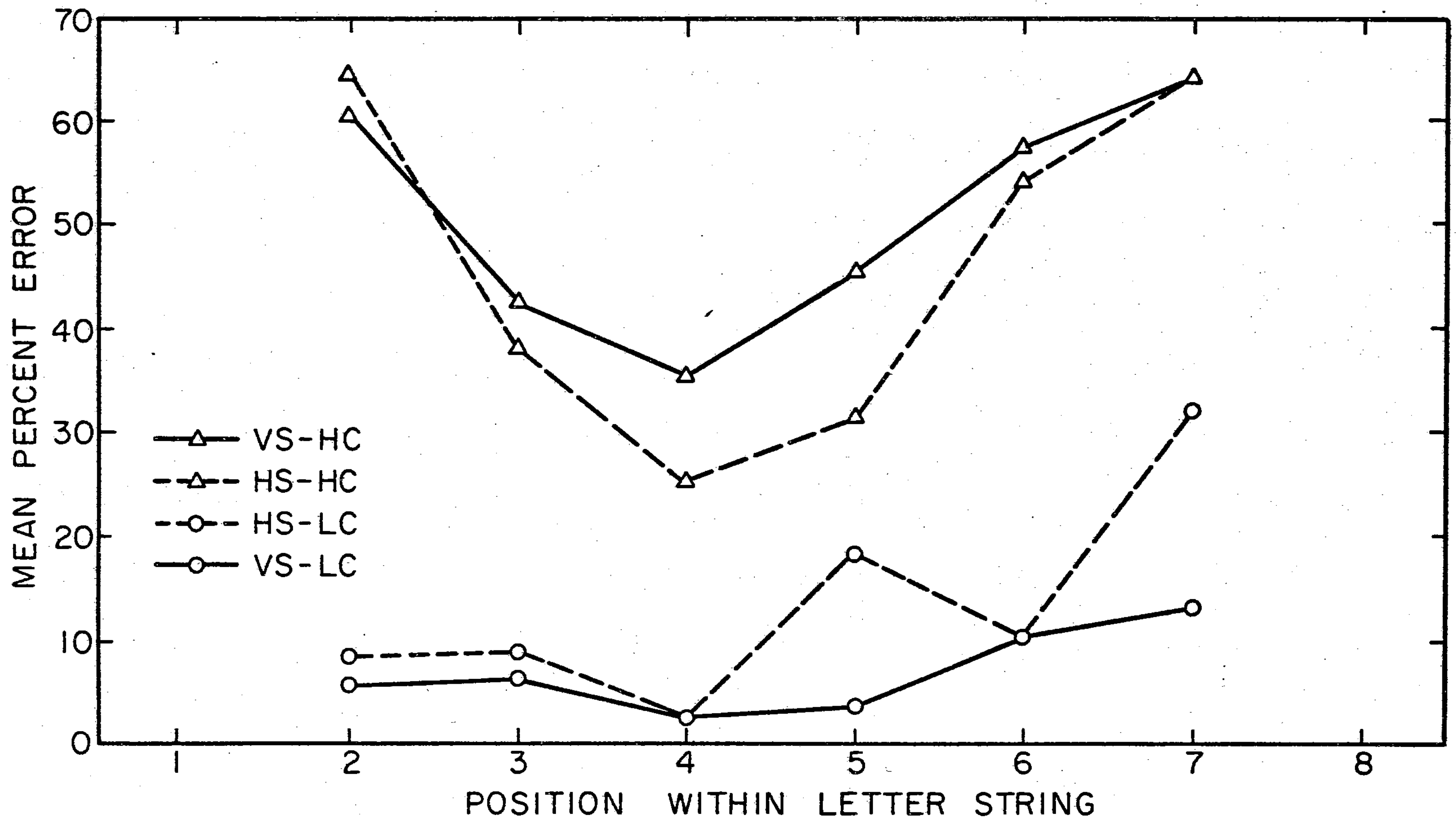

Figure 5. Missed Target Errors for Orientation and Confusion Level as a Function of String Position

TABLE II

GROUPED DATA FOR FOUR EXPERIMENTAL CONDITIONS*

Experimental Condition	Target Position					
	2	3	4	5	6	7
HS-LC	9.0	9.5	2.5	18.5	10.5	33.0
HS-HC	65.5	38.5	26.0	31.5	55.0	64.5
VS-LC	6.0	7.0	2.5	4.0	11.5	14.0
VS-HC	60.5	42.0	36.0	46.5	57.5	64.0

*Values are mean percent missed target errors.

The data was treated by an analysis of variance procedure and the summary of the results is contained in Table III. In this table it may be noted that the main effects of confusion level (A) and string position (B) were significant ($p < .01$). The two factor interactions "AxE" (presentation time with string position), "BxD" (orientation with confusion level), "DxE" (confusion level with target position) were significant. The three factor interactions "AxBxD" and "BxDxE" were significant; however, these interactions were not analyzed for simple-simple effects.

The interaction of scanning (presentation) time with string position was analyzed for simple effects. The AOV summary of these tests is contained in Table IV. Figure 6 displays the relationship of these two factors. The analysis indicated that there were no significant differences among the central position (3,4,5) errors for the two scanning times. However, the 50 msec. scanning time was associated with an elevated error rate among positions 2,6,7, and it was at these points that a significant difference in error rate was observed.

The analysis and a Newman Kuels' test indicated a significant difference ($p < .01$) between positions 2,6,7 when compared with the more centralized string positions 3,4, and 5.

The curves in Figure 6 also revealed another factor concerning the relationship of the two time durations. The relation between the curves A1 and A2 is very similar to the relationship of the (LC) and (HC) curves. The higher confusion level and shorter scanning time produce a "V" shaped curve which is indicative of a higher error rate among the lateral target positions. Low confusion and the longer scanning time (A_2) conditions reflect a relatively stable and equal error rate for all target positions.

TABLE III

ANALYSIS OF VARIANCE FOR MISSED TARGET ERRORS

Source	df	SS	MS	F/Cal
Between Subjects	19	125.05	6.58	
A (Presentation Time)	1	15.76	15.76	2.60
Subj. W. Gps.	18	109.29	6.07	
Within Subjects	940	2488.97	2.65	
B (Line Orient.)	1	0.18	0.18	0.09
AB	1	0.00	0.00	0.00
B x Subj. W. Gps.	18	34.72	1.93	
C (Viewing Meth.)	1	2.71	2.71	1.36
AC	1	0.38	0.38	0.19
C x Subj. W. Gps.	18	35.73	1.99	
D (Confusion)	1	902.88	902.88	133.96**
AD	1	0.18	0.18	0.03
D x Subj. W. Gps.	18	121.35	6.74	
E (String Position)	5	197.71	39.54	18.31**
AE	5	25.71	5.14	2.38*
E x Subj. W. Gps.	90	194.64	2.16	
BC	1	0.05	0.05	0.04
ABC	1	0.18	0.18	0.13
BC x Subj. W. Gps.	18	24.92	1.38	
BD	1	18.43	18.43	12.62**
ABD	1	6.50	6.50	4.45*
BD x Subj. W. Gps.	18	26.31	1.46	
BE	5	9.04	1.81	1.87
ABE	5	6.72	1.34	1.38
BE x Subj. W. Gps.	90	86.97	0.97	
CD	1	5.55	5.55	2.19
ACD	1	0.55	0.55	0.22
CD x Subj. W. Gps.	18	45.71	2.54	
CE	5	4.78	0.69	1.12
ACE	5	2.42	0.48	0.56
CE x Subj. W. Gps.	90	77.11	0.86	
DE	5	60.57	12.11	7.38**
ADE	5	14.62	2.92	1.78
DE x Subj. W. Gps.	90	147.54	1.64	

TABLE III Continued

Source	df	SS	MS	F/Cal
BCD	1	0.76	0.76	0.34
ABCD	1	7.88	7.88	3.53
BCD x Subj. W. Gps.	18	40.17	2.23	
BCE	5	2.74	0.55	0.50
ABCE	5	4.64	0.93	0.85
BCE x Subj. W. Gps.	90	98.07	1.09	
BDE	5	18.87	3.77	3.85**
ABDE	5	2.19	0.44	0.45
BDE x Subj. W. Gps.	90	88.33	0.98	
CDE	5	1.47	0.29	0.38
ACDE	5	3.27	0.65	0.86
CDE x Subj. W. Gps.	90	68.58	0.76	
BCDE	5	7.11	1.42	1.49
ABCDE	5	5.03	1.01	1.06
BCDE x Subj. W. Gps.	90	85.67	0.95	
Total	959	2614.02		

* = $p < .05$

** = $p < .01$

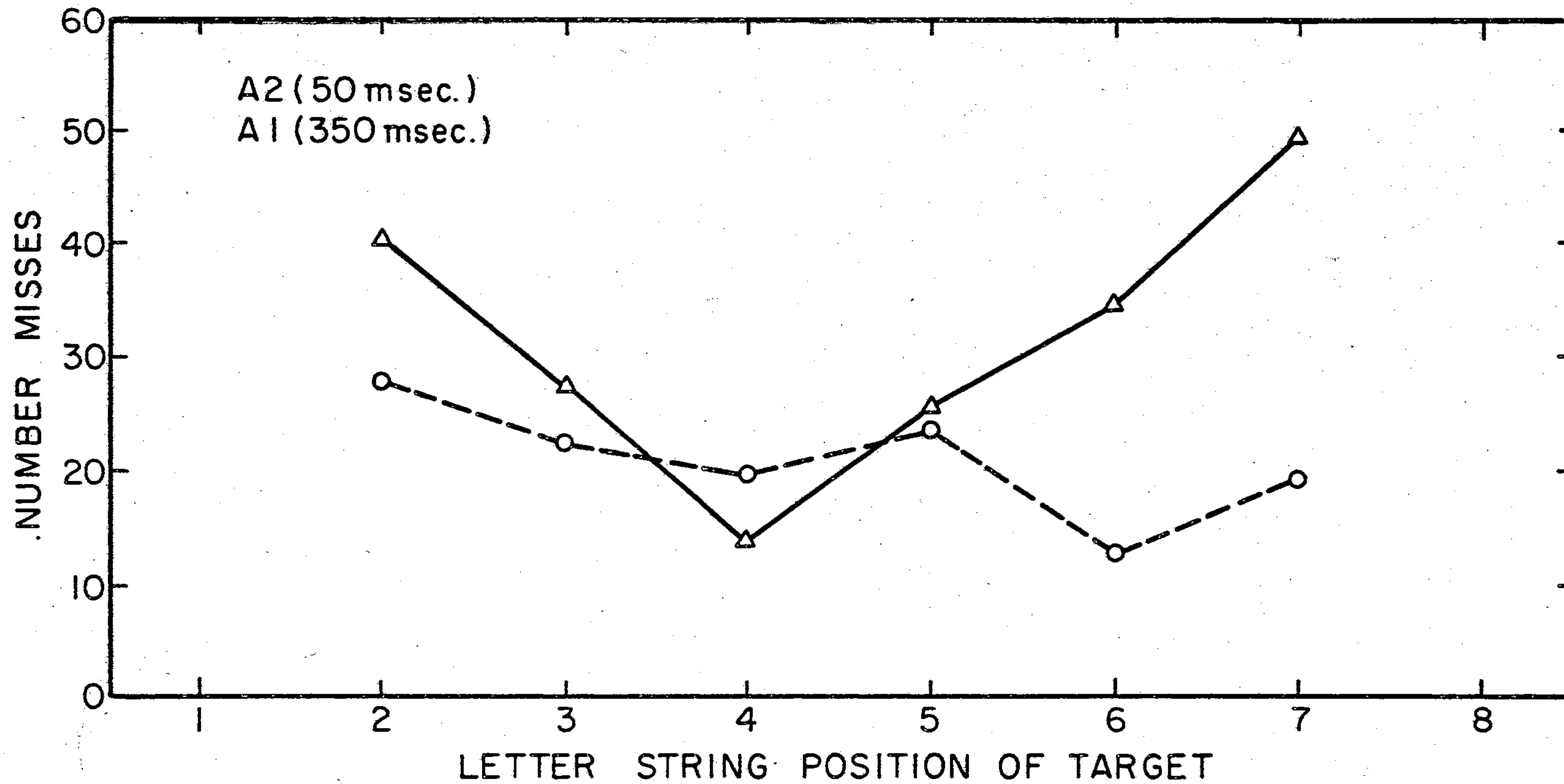

Figure 6. Interaction Between Scanning Time and Target Position

TABLE IV

ANALYSIS OF VARIANCE FOR SIMPLE EFFECTS OF SCANNING TIME AND TARGET POSITION

Source	df	SS	MS	F/Cal
Scanning Time				
at TP-2	1	16.25	16.25	5.78**
at TP-3	1	4.23	4.23	1.51
at TP-4	1	3.02	3.02	1.07
at TP-5	1	0.40	0.40	0.14
at TP-6	1	49.50	49.50	17.62**
at TP-7	1	94.55	94.55	33.65**
Error	78	219.18	2.81	
Target Position				
at A1	5	26.16	5.23	2.42*
at A2	5	158.60	31.72	14.68**
Error	90	194.40	2.16	

* = $\underline{p} < .05$
** = $\underline{p} < .01$

The interaction of orientation (B) with confusion level (D) and tests of simple effects summarized in Table V indicate the statistical significance of this interaction. A graph representation of these relationships is shown in Figure 7. From an inspection of this figure and a review of the performance curve in Figure 5, one may note that in the (LC) condition there was only a small difference in the error rate between a VS and HS string. It would appear then, that the greatest difference in error detection under both the (HS) and (VS) orientation came under the (HC) condition.

The significant interaction of confusion level with target position, and the AOV of simple effects are contained in Table VI. Graphic presentations of these effects are shown in Figure 8.

TABLE V

ANALYSIS OF VARIANCE FOR SIMPLE EFFECTS OF ORIENTATION AND VISUAL CONFUSION

Source	df	SS	MS	F/Cal
Orientation at LC	1	11.10	11.10	6.53*
Orientation at HC	1	7.50	7.50	4.41*
Error	18	30.60	1.70	
Confusion at HS	1	331.67	331.67	80.90**
Confusion at VS	1	589.64	589.64	143.81**
Error	18	73.80	4.10	

* = $p < .05$

** = $p < .01$

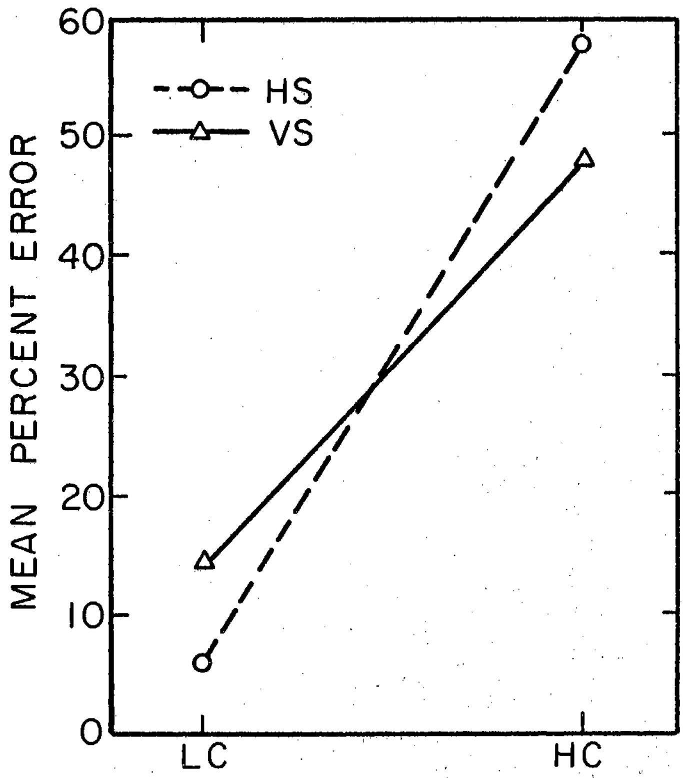

Figure 7. Interaction of Visual Confusion with String Orientation (A & B)

TABLE VI

ANALYSIS OF VARIANCE FOR SIMPLE EFFECTS OF VISUAL CONFUSION AND TARGET POSITION

Source	df	SS	MS	F/Cal
Confusion				
at TP-2	1	305.25	305.25	183.89**
at TP-3	1	102.36	102.36	61.66**
at TP-4	1	79.97	79.97	48.17**
at TP-5	1	78.40	78.40	47.23**
at TP-6	1	204.75	204.75	123.34**
at TP-7	1	191.40	191.40	115.30**
Error	78	129.48	1.66	
Target Position				
at LC	5	46.96	9.39	4.94**
at HC	5	211.32	42.26	22.24**
Error	90	171.00	1.90	

** = $p < .01$

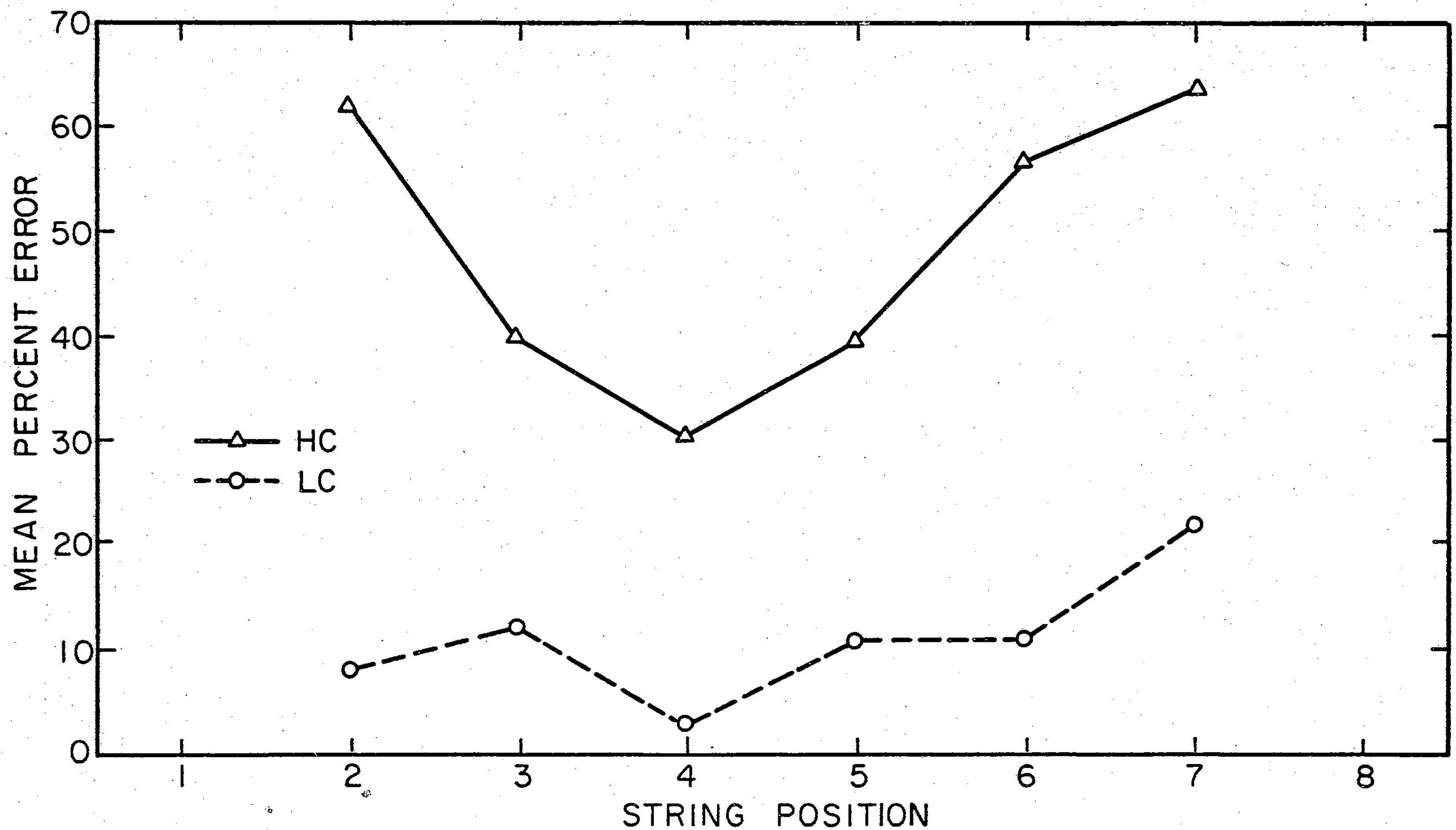

Figure 8. Interaction of Confusion Level and Target Position as a Function of Percent Error

<u>False Alarm Errors</u>: The second measure of performance in this search task was in terms of the false alarm (F/A) errors. A graph of the error trend is contained in Figure 9. The data on which these curves are based is contained in Table VII. This data was obtained in the same manner as that in Table II.

The relationship of the curves in Figure 9 fail to reveal any definite and clear trends except for an increase from left to right in the string. The AOV of these errors summarized in Table VIII confirms this also as only one of the main factors, "E" (target position) was significant. The "B x D" interaction was significant as well as 2 three factor interactions (AxBxC, BxDxE). The three factor interactions were not analyzed for simple-simple effects due to the difficulty in making a meaningful interpretation at this time.

The HS condition exhibits a difference across all positions for the two levels of confusion. Conversely the VS string presents a crisscross pattern between the HC and LC condition. In conjunction with this, there is a further confounding of results in that the two string orientations produce overlapping F/A curves for the various cell positions within the letter string.

An analysis of the simple effects of the "BxD" interaction is presented in Table IX. From the results of the AOV one can conclude that only the VS orientation produced a significant difference across all target positions for the two levels of visual confusion.

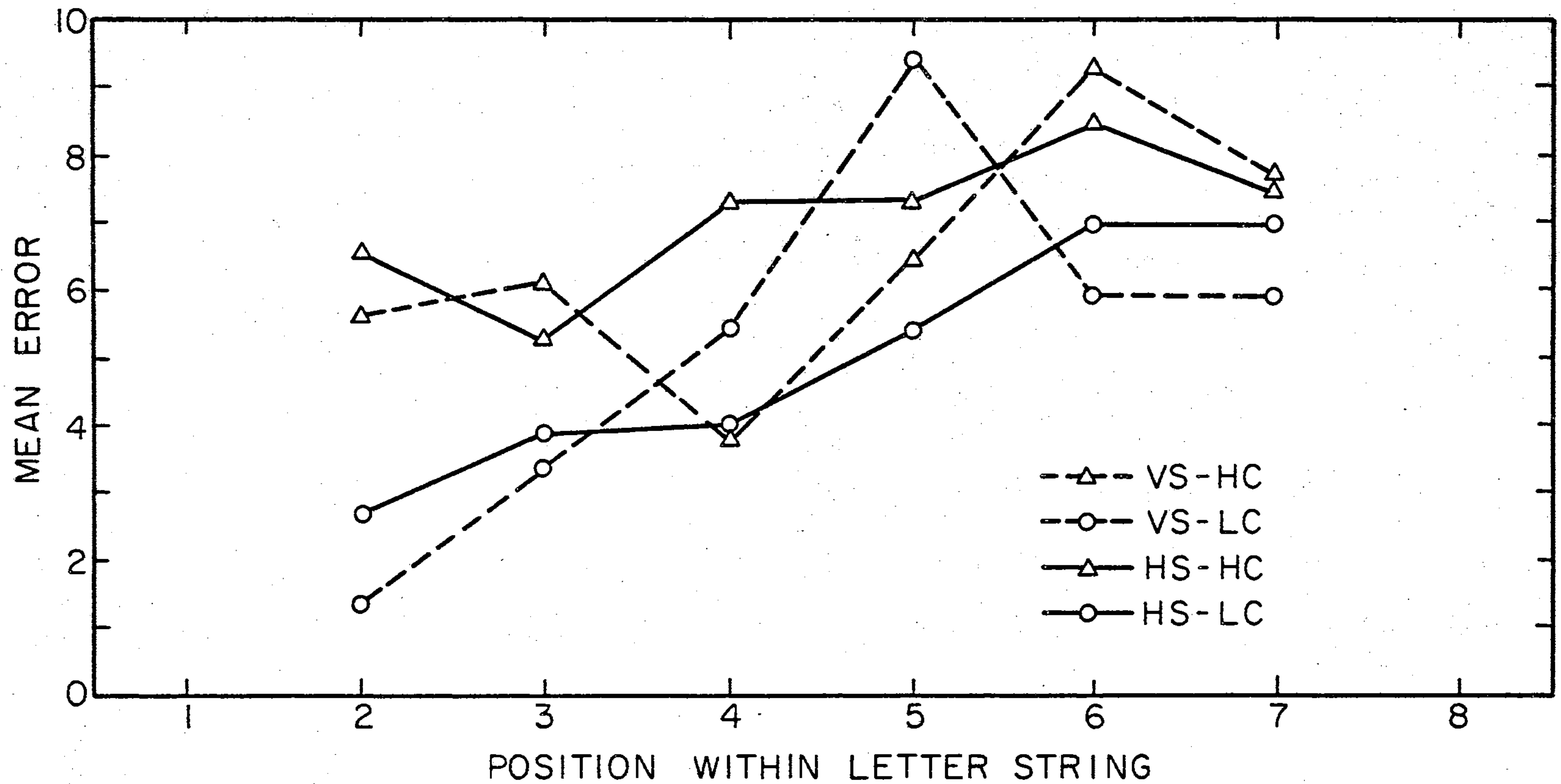

Figure 9. False Alarm Errors for Orientation and Confusion Level as a Function of String Position

TABLE VII

GROUPED DATA FOR FOUR EXPERIMENTAL CONDITIONS*

Experimental Condition	Target Positions 2	3	4	5	6	7
HS-LC	1.2	3.3	5.6	9.5	6.0	6.0
HS-HC	5.7	6.1	3.7	6.3	9.3	7.8
VS-LC	2.7	3.6	3.8	5.5	7.1	7.1
VS-HC	6.4	5.2	7.2	7.3	8.5	7.3

*Values are mean number of false alarm errors

TABLE VIII

ANALYSIS OF VARIANCE FOR FALSE ALARM ERRORS

Source	df	SS	MS	F/Cal
Between Subjects	19	1712.88	90.15	
A (Scanning Time	1	1.67	1.67	0.02
Subj. W. Gps.	18	1711.21	95.07	
Within Subjects	940	3335.11	3.55	
B (Line Orient.)	1	1.07	1.07	0.41
AB	1	5.70	5.70	2.16
B x Subj. W. Gps.	18	47.52	2.64	
C (Viewing Meth.)	1	0.60	0.60	0.16
AC	1	3.50	3.50	0.94
C x Subj. W. Gps.	18	67.36	3.74	
D (Confusion)	1	52.27	52.27	3.16
AD	1	36.04	36.04	2.18
D x Subj. W. Gps.	18	297.32	11.52	
E (String Position)	5	144.56	28.91	3.21**
AE	5	28.67	5.73	0.64
E x Subj. W. Gps.	90	809.64	9.00	
BC	1	2.20	2.20	0.76
ABC	1	17.07	17.07	5.87*
BC x Subj. W. Gps.	18	52.44	2.91	
BD	1	7.00	7.00	4.67*
ABD	1	2.02	2.02	1.35
BD x Subj. W. Gps.	18	27.03	1.50	
BE	5	13.80	2.76	1.34
ABE	5	5.63	1.13	0.55
BE x Subj. W. Gps.	90	185.53	2.06	
CD	1	0.34	0.34	0.09
ACD	1	17.07	17.07	4.38
CD x Subj. W. Gps.	18	70.13	3.90	
CE	5	7.79	1.56	1.24
ACE	5	7.36	1.47	1.17*
CE x Subj. W. Gps.	90	113.64	1.26	
DE	5	41.82	8.36	2.03
ADE	5	15.32	3.06	0.74
DE x Subj. W. Gps.	90	370.47	4.12	

TABLE VIII Continued

Source	df	SS	MS	F/Cal
BCD	1	0.02	0.02	0.01
ABCD	1	0.00	0.00	0.00
BCD x Subj. W. Gps.	18	36.77	2.04	
BCE	5	25.73	5.15	2.07
ABCE	5	9.05	1.81	0.73
BCE x Subj. W. Gps.	90	224.26	2.49	
BDE	5	29.48	5.90	2.72*
ABDE	5	4.65	0.93	0.43
BDE x Subj. W. Gps.	90	195.58	2.17	
CDE	5	2.52	0.50	0.32
ACDE	5	2.77	0.55	0.36
CDE x Subj. W. Gps.	90	138.91	1.54	
BCDE	5	20.80	4.16	2.01
ABCDE	5	7.08	1.42	0.69
BCDE x Subj. W. Gps.	90	186.58	2.07	
Total	959	5047.99		

* = $p < .05$

** = $p < .01$

TABLE IX

ANALYSIS OF VARIANCE FOR SIMPLE EFFECTS OF STRING ORIENTATION AND VISUAL CONFUSION

Source	df	SS	MS	F/Cal
Orientation at (LC)	1	1.30	1.30	0.63
Orientation at (HC)	1	6.77	6.77	3.27
Error	18	37.26	2.07	
Confusion at (Horizontal) HS	1	10.50	10.50	1.17
Confusion at (Vertical) VS	1	49.77	49.77	5.52*
Error	18	162.18	0.01	

* = $p < .05$

Discussion

One of the major findings of this experiment was considered to be the consistent difference in the patterning of target detection errors that exist between the two levels of visual confusion as employed in this study. This difference on both a quantitative and qualitative basis was consistently demonstrated over the various combinations of experimental conditions.

Under the (HC) condition fewer errors occurred in the central target positions than in the lateral positions. This finding is comparable with the results reported by Averbach and Coriell (1961) and Mackworth (1965).

The (LC) condition typically produced a flat curve suggesting that there was little difference among the target positions and the detection errors.

The greater precision in detecting targets when they occupy the central target positions can be attributed to the same processes that Mackworth (1965) proposed. Mackworth feels that the mere presence of non-target letters function as a background of noise in conjunction with the target being present as a signal. Therefore, viewing search behavior from a signal detection viewpoint, this study involved detecting a signal from two different noise levels.

This noise, according to Mackworth, impairs both the periphreal and foveal recognition of figures. The disturbance of periphreal areas is very similar in effect to the tunnel vision created by a physiological defect in the optic system. In light of this, one can consider the experimentally induced phenomenon as a type of functional tunnel vision.

This theoretical basis provides the most meaningful interpretation and understanding of the results obtained in this study. The remaining discussion will be from this theoretical framework.

The physical description of the stimulus line can be best made in terms of its size in relation to the visual angle it subtended and the retinal area stimulated. The visual angle subtended by the stimulus string on both a horizontal and vertical axis was less than 3.5°. This is considered to be within the angular limits (Miller, 1949) normally attributed to being within the foveal limits of vision.

Considering the width of this angle as an area to be scanned, one may propose that the highest detection rate of a target letter would occur when only the target itself was present in this area. Also, one can speculate that it would be detected equally as well in any portion of this area. The addition of other letters in this space in conjunction with a target would constitute a signal presentation with a noise. In this case, for the S to detect the target letter (signal), he would have to employ a higher order cognitive process to differentiate the signal from the surrounding noise. It is under this condition that the search behavior was studied in this experiment.

The area that the stimulus string occupied may be labeled as the "useful field of view", using Mackworth's terminology. He defines this useful field of view as an area around the fixation point from which information is briefly stored and read out during a visual task.

The limits of this field vary as a function of the size or amount of information input to the visual system. It is suggested that this visual channel has a limited capacity for processing information on both a quantitative and qualitative basis.

When the quantity of information exceeds a certain limit, or when the stimulus exceeds a certain degree of complexity, this field contracts in size to prevent over-looking the visual system.

Mackworth has drawn an analogy of this type of constriction to that constriction performed by the pupil in limiting the amount of light entering the eye. The relative size of the functional visual field varies from moment to moment, governed by the type and amount of information available for processing.

The maximal area of this field is limited by the physiological characteristics of the eye itself. It is generally conceded that the greatest visual acuity and discrimination of forms occurs within the foveal area which has the greatest concentration of cone receptors.

The reduction of this visual field by visual noise is ably demonstrated by the two levels of target/background confusion used in this experiment. Although the confusion levels were equated on area size, a difference resulted in the size of the useful field measures by the positional error rate.

This can be explained in that under the (LC) condition the error rate for all the target positions was, generally speaking equal. Thus allowing this as an acceptable error rate, one may consider it as one measurement of the useful visual field. The amount and distribution of noise in this field would be expressed in terms of the amount and distribution of missed targets. Under the (LC) condition one may consider that the signal to noise ratio was equivalent for all target positions within the letter string.

However, under the (HC) condition the noise level was such that detection of the signal was much more difficult, and also that it required a longer time to make the necessary identification. The effective contraction of the useful visual field in this instance can be demonstrated in that the error rates among the lateral target position were greatly inflated in comparison to the central positions. The error rates for the lateral positions were in excess of 50%. Considering a 50% detection rate as a threshold level, it can be stated that the useful field contracted from a width of six letters, to that of three letters wide.

Another factor that was effective in causing a reduction in the size of the viewing field was the time available for scanning the stimulus strings under a (HC) condition. This conclusion is also supported by the findings of Volkmann (1964), Chaikin et al. (1962), and Mackworth (1965) which supported the notion that the width of the useful field is a function of the scanning time allotted. It is proposed that there is some type of scan or read-out of information from the center of the stimulus outwards to its lateral dimension. Support for this notion, in respect to differences in scanning time, is obtained from the significant "AxE" interaction of missed targets. This interaction of scanning time and errors in target positions suggest a relationship between the two scanning times under (HC) conditions to be similar to that between the two confusion levels. That is, if the scan is considered to begin sequentially from the center of the letter string proceeding in both directions, then larger errors would be expected in the lateral target positions with a shorter viewing time. To state it more simply, if scanning is based upon processing a number of letters per unit of time, then the shorter the scanning time the fewer letters processed, and in this case the fewer the errors in the central target positions.

False alarms, the second measure of performance in this experiment failed to be as sensitive as the missed target errors. It would appear that although there were significant differences among the target positions and F/A rate, the multiple interactions between the experimental variables precluded any useful interpretations at this time. It was interesting in that there was not a corresponding increase of F/A errors between the two levels of visual confusion as there was in comparing the error rate of misses under low and high confusion. In going from the LC to HC conditions there was approximately a 900% increase in missed targets while the F/A rate increased only about 50%.

In summary, the high confusion visual level produced a decrement in detection of target letters; however, only a moderate increase in F/A occurred. From this, one may state that the different measures of errors are based upon different cognitive functions and, thus, cannot be directly compared with each other.

CHAPTER III

EXPERIMENT II: VISUAL SEARCH BEHAVIOR AS A FUNCTION OF FIELD VELOCITY

The ability of an individual to make the necessary visual discriminations in a visual search task is based upon various perceptual skills, not the least of which is visual acuity. One of the major factors which affects acuity (aside from illumination, viewing time, brightness-contrast, etc.) is movement. Movement of the visual field or objects within it occur when the individual is moving; when the field is moving, or when there is combined movement of the individual and the field.

One of the functions of this experiment was to investigate the effects of field velocity upon search behavior. A secondary function was to provide data on search behavior in a dynamic field which could be compared with search behavior in a static field.

The relative function, importance, and measurement of acuity in static and dynamic fields are not believed to be equivalent as evidenced by Burg and Hulbert's (1961) research. They have found little or no correlation between acuity in a static and dynamic field. The tests of visual acuity in a moving field have usually involved identification of a single target moving through the visual field. The measure of acuity under these conditions has been termed dynamic visual acuity (DVA). The measurement of DVA and its deterioration has generally been made in terms of the angular velocity of the target.

General conclusions regarding DVA have been that: 1) acuity for a moving target decreases as the angular velocity of the target increases; 2) performance in a given test can be improved both with practice and with better target illumination; and 3) these findings are generally valid regardless of the plane or direction of movement and for the various combinations of movement between the field and the individual.

This experiment had many features common to tests of DVA. As DVA is a function of movement, this study was concerned with differential effects on scanning behavior that could be attributed to different target velocities.

Method

Stimulus Materials: Capital letters were used as stimuli. Eight letters made up a stimulus string which was 1/8" X 1" in dimensions. There were twelve lists each composed of 24 eight-letter strings; one string to a line. Twelve of these letter strings in each list were made from a pool of low visual confusion letters, and the remaining half of the letter strings were derived from a pool of high visual confusion letters in the same manner as described in the "Method" section of Experiment I.

Apparatus: Lists of letter strings were exposed on a moving, continuous belt apparatus, that could be most simply described as an enlarged version of a memory drum. A picture of this equipment is shown in Figure 10. Different belt speeds were achieved through a combination of gearing and a variable drive motor. Variations in the belt speed produced corresponding changes in the velocity at which the letter strings moved through a viewing aperture.

Single letter strings moving at velocities V1 and V2 (0.66 in/sec., 2.0 in/sec., respectively) were displayed through one of the two size

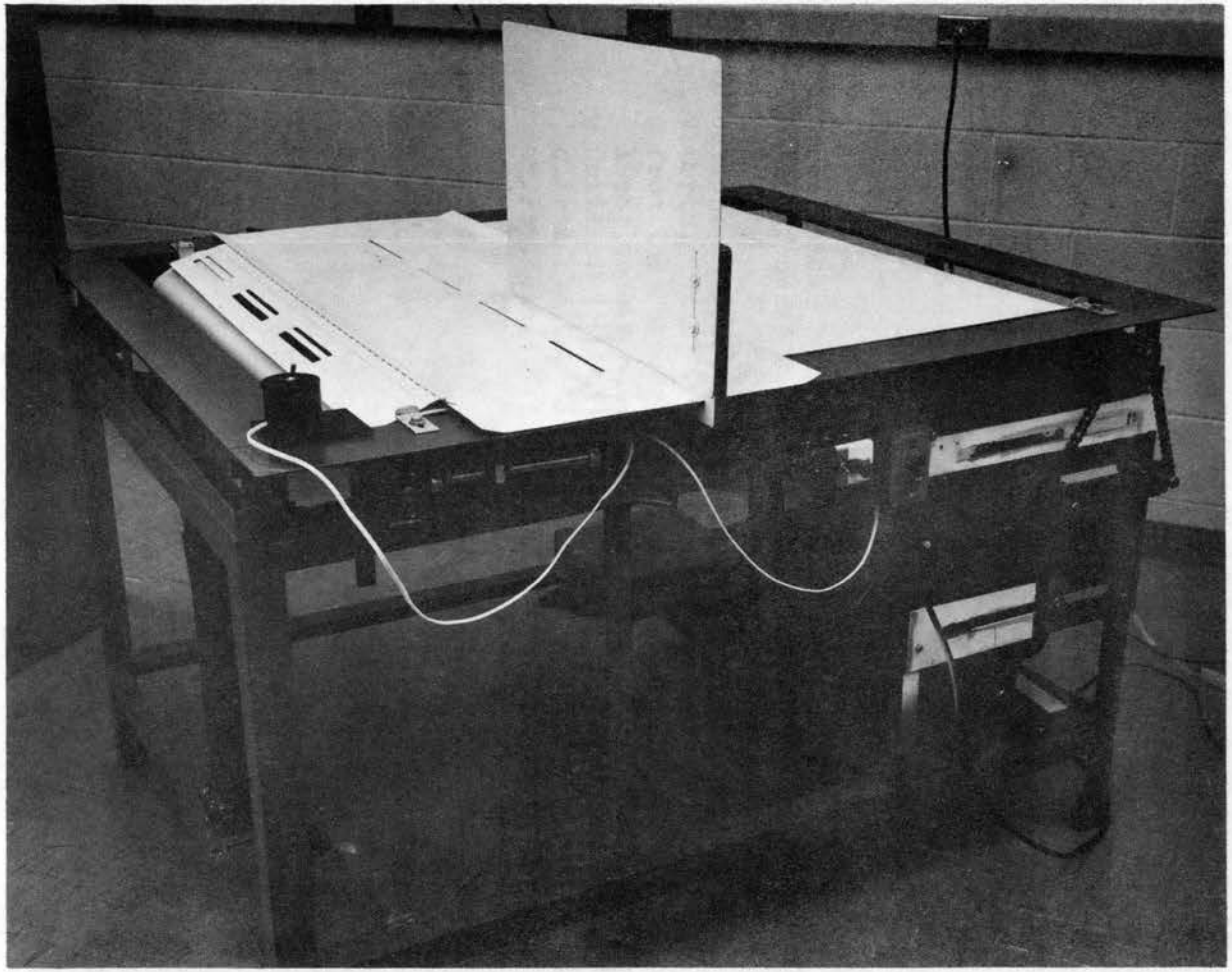

Figure 10. Experimental Apparatus

of viewing aperture. The aperture dimensions were 0.25 X 2.0 and 0.50 X 2.0 inches for string velocities V1 and V2 respectively. These viewing apertures were part of an overall exposure shield which limited the S's field of view to the task at hand. All surfaces of this shield were painted with a low gloss white paint.

Experimental Variables: 1) String velocity (V1, V2). Horizontal letter strings moved in both a North to South and South to North direction through the viewing apertures at velocities V1 and V2. Stimulus lines moved through the smaller viewing aperture at V1 and through the larger aperture at V2. Converted into angular velocity, V1=2.1 deg/sec., and V2=6.25 deg/sec. The association of a given velocity with a specific size aperture was necessary to equate the time that an intact stimulus line remained in view for the two stimulus speeds. Table X contains more information on the interrelationships of velocity, exposure time and aperture size.

2) Target/Background Confusability: The relationship between the target letter and the background letters was carried out in the same manner as in Experiment I, with the following exceptions. For the LC condition a single target letter "K" was embedded in a line of the following letters, (A,B,O,D,C,G,I,T). The HC condition consisted of the target letter "K" and the letters (N,L,F,H,X,V,Y,R).

3) Target Positions (TP): As in the first experiment there were six target positions, (TP: 2-7), each numbered according to its cell position within the eight letter stimulus string.

Experimental Design: The design of this experiment was a 2 X 2 X 6 split plot factorial design with repeated measures on the last two factors (Kirk, 1968). The first factor, Velocity, was a between-Ss variable. The factors of visual confusion (HC, LC) and target position

TABLE X

RELATIONSHIP OF VELOCITY AND EXPOSURE TIME TO APERTURE SIZE

Unit Measure	Aperture 1	Aperture 2
Linear velocity	V1=.66 in/sec.	V2=2.0 in/sec.
Angular velocity	V1=2.1 deg/sec.	V2=6.25 deg/sec.
Time for a point to traverse aperture	379 msec.	250 msec.
Exposure duration for any portion of the letter string	562.5 msec.	312.5 msec.
Exposure duration of an intact letter string	187.5 msec.	187.5 msec.

(TP2-7) were within Ss effects.

Stimulus Presentation and Response Recording: A trial consisted of the following events: 1) The S would look at the viewing aperture. 2) A narrow black "cuing" line, extending the length of the viewing aperture, would appear and pass through the aperture. 3) One second later the stimulus string would move through the aperture. 4) The S would then record his response on the answer sheet, as in Experiment I, and afterwards return his attention to the viewing aperture. Trial presentation was controlled by E. The interval between trials was approximately 5 seconds which allowed the S adequate time to record his response and redirect his attention to the viewing aperture.

Procedure: All Ss were tested individually and were assigned to a particular experimental group and a sequence of experimental conditions according to a predetermined randomization schedule.

At the beginning of the experimental session the S was seated comfortably in front of the viewing aperture and instructed in the method of stimulus presentations and in the manner in which to record his responses. During this time the E checked the alignment of the viewing aperture with the stimulus strings. Prior to the beginning of the practice trial each S was read the instructions as contained in Appendix B. After these instructions were given to the S the practice trials were begun. After each presentation of a stimulus line the E checked the S's response for accuracy and informed the S as to the correctness of his answer. Each S was given 24 practice trials on both levels of visual confusion. The practice involved an equal number of stimulus lines moving in the two directions and at the velocity that he would be later tested. All Ss demonstrated an acceptable (less than a 20% missed target error under the LC condition) level of task performance by the end of these practice trials.

Subjects: Twenty introductory psychology students at Oklahoma State University volunteered for this study, and received course credit points for their participation. Two groups, each consisting of five male and five female Ss, were organized according to a randomization process with the restriction that the number of sexes in each group was equal. The Ss were tested for normal near vision with a Federal Aviation Administration form #2917.

Scoring of Responses: As in Experiment I, the Ss' responses were scored according to the particular type error committed. These errors were classified as either misses or false alarms. In turn, these errors were scored according to an easy criterion (E) and a hard crition (H).

Under criterion "E", a miss occurred only when the S did not detect the presence of a target letter in a line, and a F/A was scored when the S indicated a target being in a letter string when it was not. Under this criteria a given line could contain only one of the two error types.

Under criterion "H" a miss was scored when the S failed to detect a target, and when the S indicated the position of a target as more than one cell position to either side of its actual location. A second type F/A was scored for the position that the S indicated the target was in, when it was actually more than one position away. Under this criterion a given target line could contain both a miss and F/A error.

Results

Task performance was measured and analyzed on the basis of missed targets and F/A errors for both scoring criteria. The data analyzed and presented in this section was under scoring criterion "H", the more stringent scoring method. Comparable data analysis under criterion "E" is contained in Appendix B.

Performance summed over all experimental conditions is contained in Table XI. As may be seen from this table the total error rate including both misses and F/A errors was 17.7 percent. Ss failed to properly identify a target on 24.7% of the stimulus strings which contained a target letter, while their F/A rate was 10.4 percent. The differential effect of the HC and LC conditions on missed targets and F/A was more clearly demonstrated in this study than in Experiment I.

Missed Target Errors: The curves plotted in Figure 11 represent the percent of missed targets for stimulus string velocities V1 and V2 under both HC and LC conditions. It may be noted the similarity between the curves of V1 and V2. As in Experiment I, the HC condition was associated with a "modified V" shape curve which indicated a higher error rate among the lateral target positions. The LC condition provided a lower overall position error rate, and for V1 the target position errors were relatively constant. The condition V2-LC exhibited an interesting trend in that the terminal target positions reflected a higher error rate than did the central positions. A Newman Keuls' test revealed that the terminal target positions (2,7) were significantly different from the other positions at $p < .05$. Under V1-LC only target position 2 was significantly different ($p < .05$) while other comparisons between position means were insignificant. An analysis of variance was conducted on the number of errors for each S, and the results are summarized in Table XII. In this analysis it was noted that there were no significant differences between V1 and V2. Visual confusion and target position factors were significant beyond the $p < .01$ level as well as their interaction. These findings are in agreement with the trends in Figure 11. The Confusion X Target Position interaction was analyzed for simple effects and

TABLE XI

A SYNOPSIS OF EXPERIMENTAL TASK PERFORMANCE

Total number of stimulus lines presented	5,760
Number of lines scored as errors (misses + F/A)	1,025
Percent total error	17.7%
Number of lines containing a target	2,880
Number of lines scored as misses	713
Percent missed targets	24.7%
Number of lines not containing a target	2,880
Number of lines scored as F/A	310
Percent F/A	10.4%
Number of LC target lines	1,440
Number of lines scored as misses	128
Percent missed targets	8.8%
Number of HC target lines	1,440
Number of lines scored as misses	585
Percent missed targets	40.6%
Number of LC nontarget lines	1,440
Number of lines scored F/A	85
Percent F/A	5.9%
Number of HC nontarget lines	1,440
Number of lines scored as F/A	225
Percent F/A	15.6%

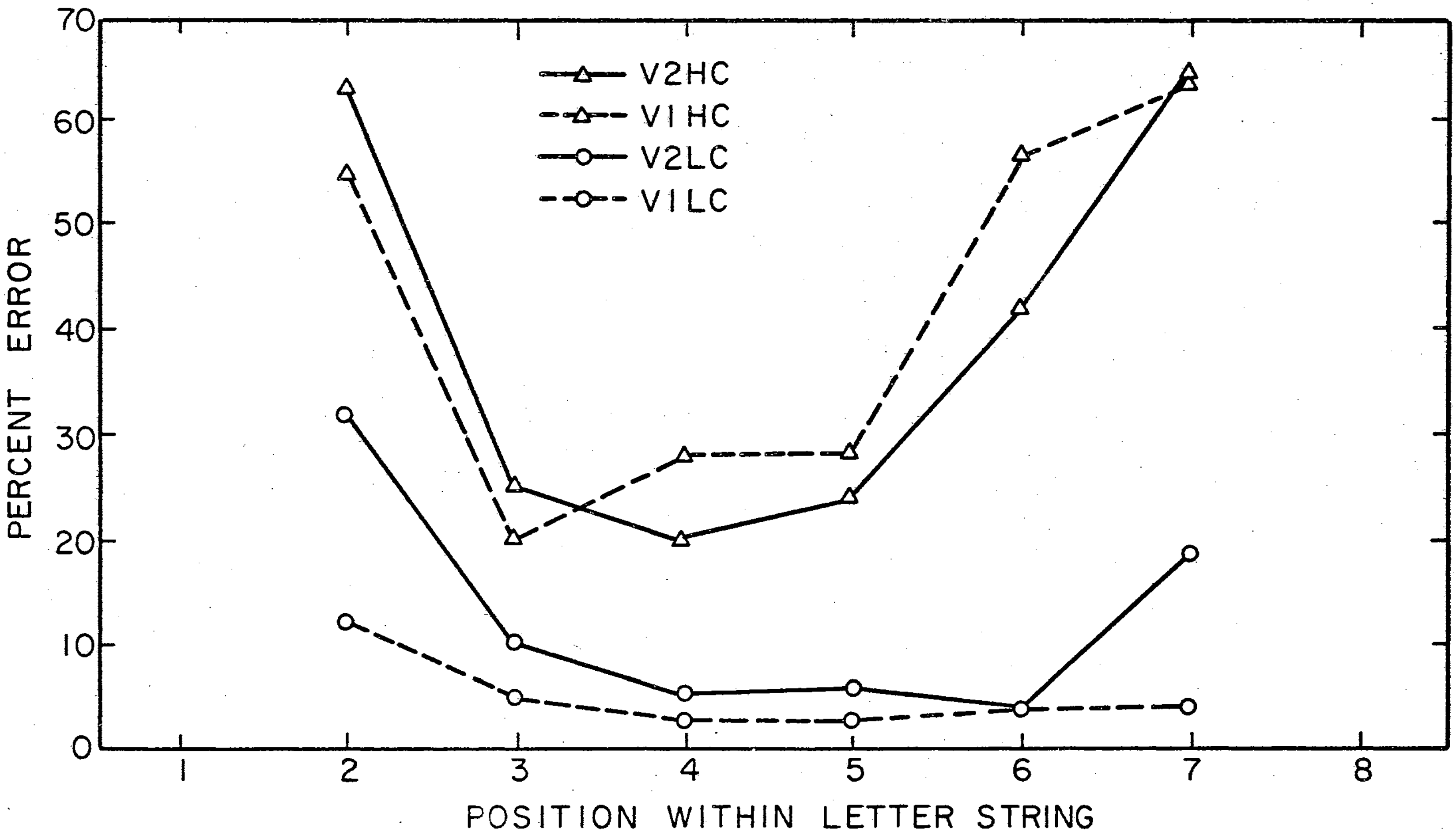

Figure 11. Average Percent Misses for Target Position as a Function of Velocity and Confusion Level

TABLE XII

ANALYSIS OF VARIANCE FOR MISSED TARGET ERRORS

Source	df	SS	MS	F/Cal
Between Subj.	19	185.55	9.77	
A(Velocity)	1	6.34	6.34	0.64
Subj. W. Gps.	18	179.21	6.96	
Within Subj.	220	2271.24	10.32	
B (Confusion)	1	870.20	870.20	162.96**
AB	1	19.84	19.84	3.72
B x Subj. W. Gps.	18	96.04	5.34	
C (String Pos.)	5	417.07	83.41	17.16**
AC	5	42.24	8.45	1.74
C x Subj. W. Gps.	90	437.44	4.86	
BC	5	167.87	33.57	13.99**
ABC	5	4.94	0.99	0.41
BC x Subj. W. Gps.	90	215.60	2.40	
Total	239	2456.79		

** = $p < .01$

the results of this test are contained in Table XIII. A graphic representation of these effects are illustrated in Figure 12. Again the differences in error patterning for the two confusion levels is accentuated. The AOV of these simple effects revealed significant differences ($\underline{p}<.01$) between confusion levels over all target positions. There were also significant differences ($p<.01$) between the target positions for each level of visual confusion. Another feature of Figure 12 is that of the significant differences between the target positions at each level of confusion. This is demonstrated in the rise in error rate among the lateral target positions for the LC condition. In the HC condition, the difference in target positions is most noticeable among a comparison of string positions; 2,6,7, with the central string positions 3,4, and 5.

<u>False Alarm Errors</u>: Performance measured by the number of F/A per target position is graphically displayed in Figure 13. The values in graph are based upon the total number of F/A per target position. The scoring method of criterion "H" necessitated using totals rather than percents in that a F/A could be scored for a yes/response to a target line, as well as a non-target line, thereby leaving undetermined the base for a percentage. An AOV was performed on these errors and the results are presented in Table XIV. As in the case of missed target errors, confusion level, target position and the interaction of these factors were significantly different ($\underline{p}<.01$). It is to be noted that letter string positions 1 and 8 were included in this analysis as there was a small number of F/A errors made in these positions, but they are not due to an artifact.

A test of simple effects for confusion level and letter string position was made and the results are listed in the AOV summary in Table XV. This analysis indicated that there were significant ($\underline{p} < .01$)

TABLE XIII

AOV SUMMARY OF SIMPLE EFFECTS FOR CONFUSION AND TARGET POSITION INTERACTION

Source	df	SS	MS	F/Cal
Visual Confusion at				
TP-2	1	189.22	189.22	65.47**
TP-3	1	32.40	32.40	11.21**
TP-4	1	60.02	60.02	20.77**
TP-5	1	62.50	62.50	21.63**
TP-6	1	297.02	297.02	102.78**
TP-7	1	369.90	369.90	137.34**
Error	78	225.42	2.89	
Target Pos. at				
LC	5	76.07	15.21	4.19**
HC	5	508.87	101.77	28.04**
Error	54	196.02	3.63	

** = $p < .01$

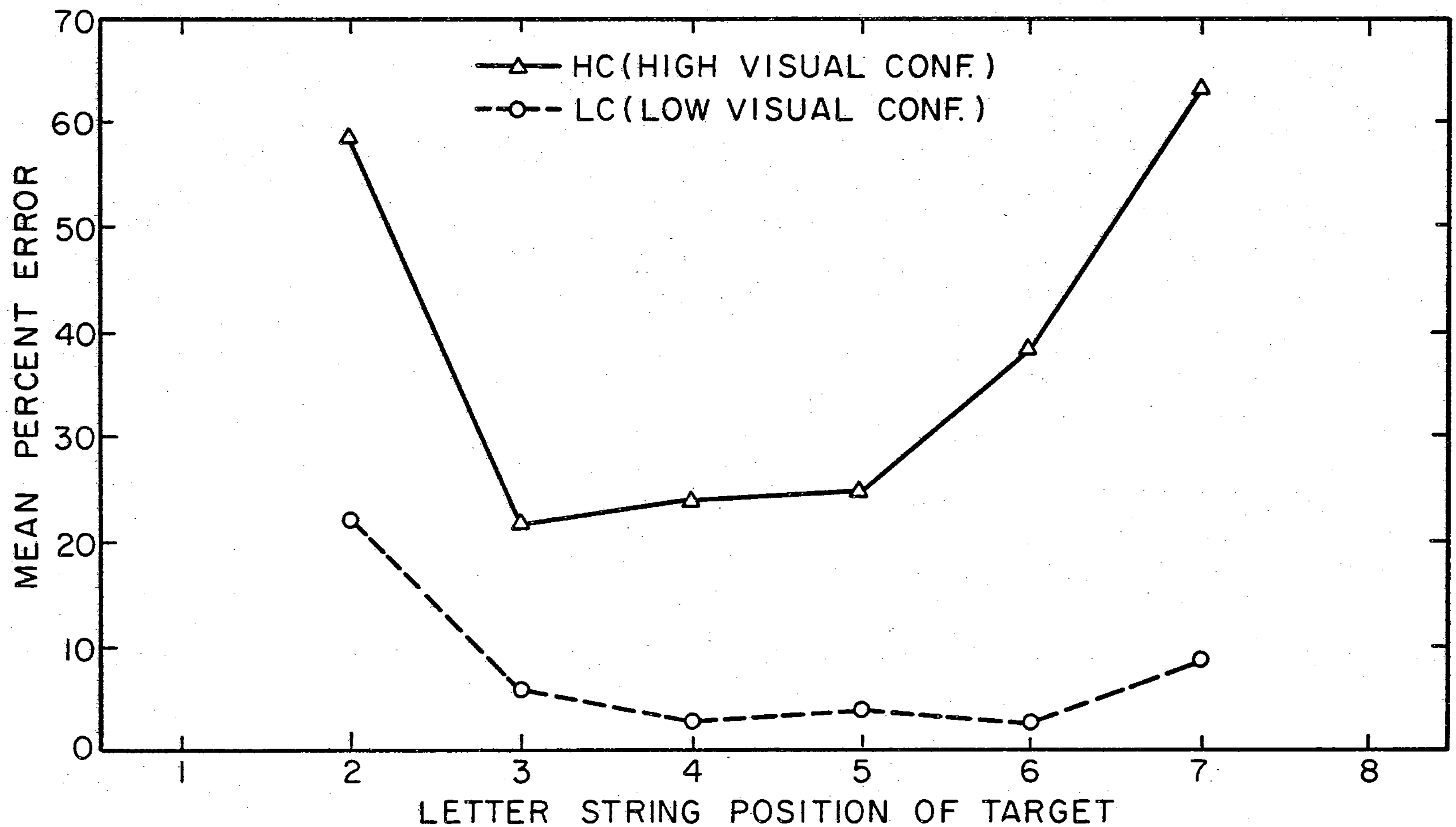

Figure 12. Interaction Between Confusion Level and Target Position

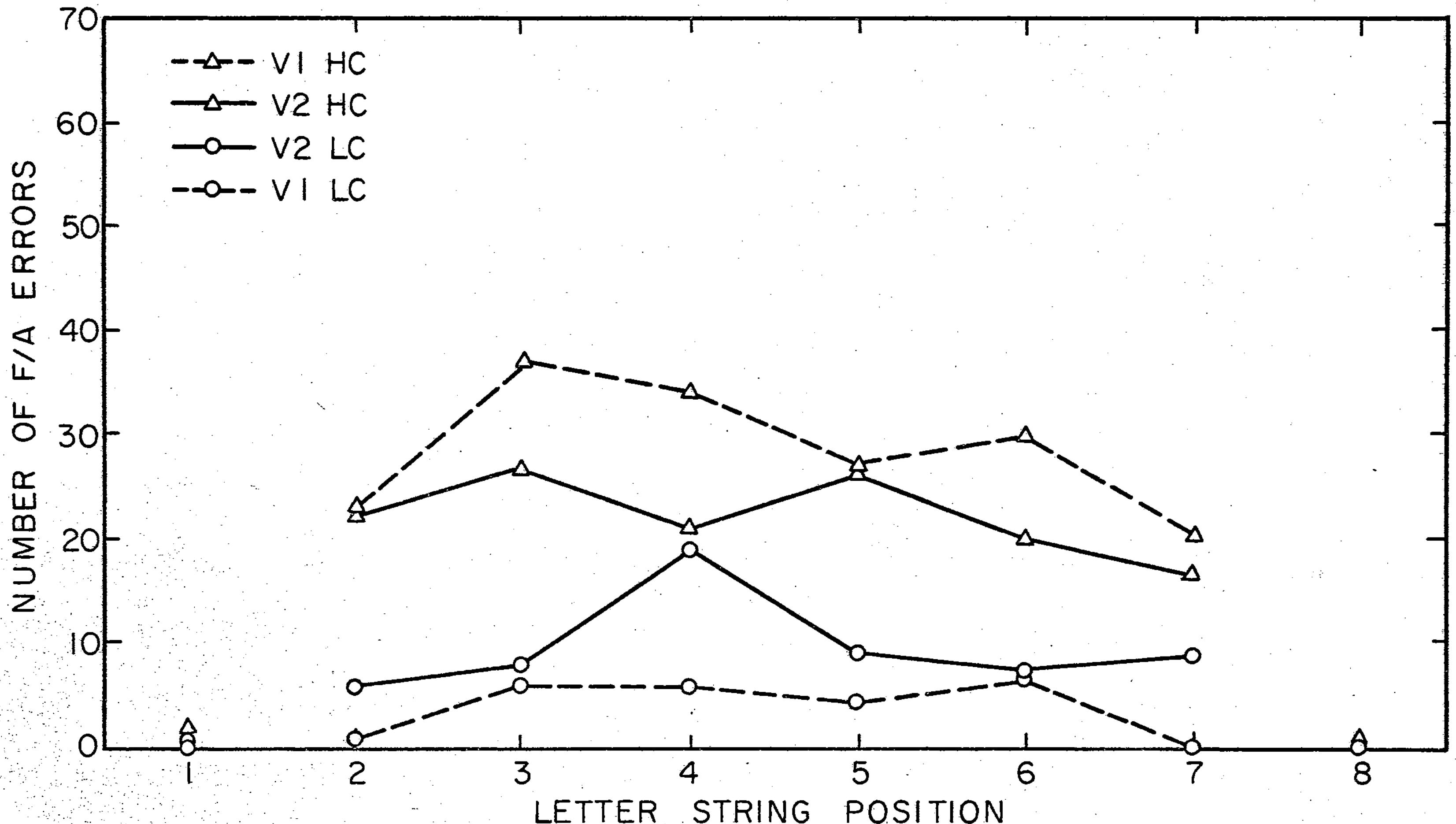

Figure 13. Total Number of False Alarm Errors as a Function of String Position

TABLE XIV

ANALYSIS OF VARIANCE SUMMARY TABLE FOR FALSE ALARM ERRORS

Source	df	SS	MS	F/Cal
Between Subj.	19	261.30	13.75	
A (Velocity	1	0.01	0.01	0.0007
Subj. W. Gps.	18	261.29	14.52	
Within Subj.	300	1156.50	3.86	
B (Confusion	1	162.45	162.45	23.17**
AB	1	15.31	15.31	2.18
B x Subj. W. Gps.	18	126.24	7.01	
C (String Pos.)	7	164.85	23.55	8.04**
AC	7	5.34	0.76	0.26
C x Subj. W. Gps.	126	369.31	2.93	
BC	7	55.30	7.90	4.05**
ABC	7	11.54	1.65	0.85
BC x Subj. W. Gps.	126	246.16	1.95	
Total	319	1417.80		

** = $p < .01$

TABLE XV

AOV SUMMARY OF SIMPLE EFFECTS FOR CONFUSION AND LETTER STRING INTERACTION ON FALSE ALARM ERRORS

Source	df	SS	MS	F/Cal
Visual Confusion at				
TP-1	1	0.23	0.23	0.09
TP-2	1	40.65	40.65	15.76**
TP-3	1	62.50	62.50	24.22**
TP-4	1	22.50	22.50	8.72**
TP-5	1	42.02	42.02	16.29**
TP-6	1	34.22	34.22	13.26**
TP-7	1	18.22	18.22	7.06**
TP-8	1	0.03	0.03	0.01
Error	112	288.96	2.58	
Target Pos. at				
LC	7	22.47	3.21	1.32
HC	7	197.67	28.24	11.57**
Error	66	161.04	2.44	

** = $p < .01$

differences between letter positions 2-7, but that for letter positions 1 and 8 there were no significant differences attributable to the different levels of visual confusion. The LC condition did not contain any significant differences between the eight letter positions. However, the HC condition did indicate a difference between the letter string positions, but this was primarily due to positions 1 and 8 being included. Disregarding their effects, an inspection of Table XV reveals a fairly consistant level of errors among the six target positions for the HC condition. Thus, there is a different F/A error rate associated with each level of visual confusion.

It was mentioned earlier that two scoring criteria were used in this experiment. The relationship between these scoring methods can be easily seen by an inspection of Figure 14. This graph represents the relative difference between the two scoring criteria for scoring missed targets that occurred while scanning the target lines at V1. The relationship of the curves reveal that criterion "H" yielded a slightly elevated error rate; however, this error rate is closely related to that measured by criterion "E". The feature of major importance was that under LC there was a small difference between the two scoring methods, while under HC conditions the relative difference increased. This would indicate another possible effect of visual confusion. Not only is it hard to detect a target, but it is also more difficult to locate its position or, on the other hand, one can miss the actual target and make a F/A. This again emphasizes the powerful effects of visual confusion on search behavior.

Discussion

The major purpose of this experiment was to compare the effects of

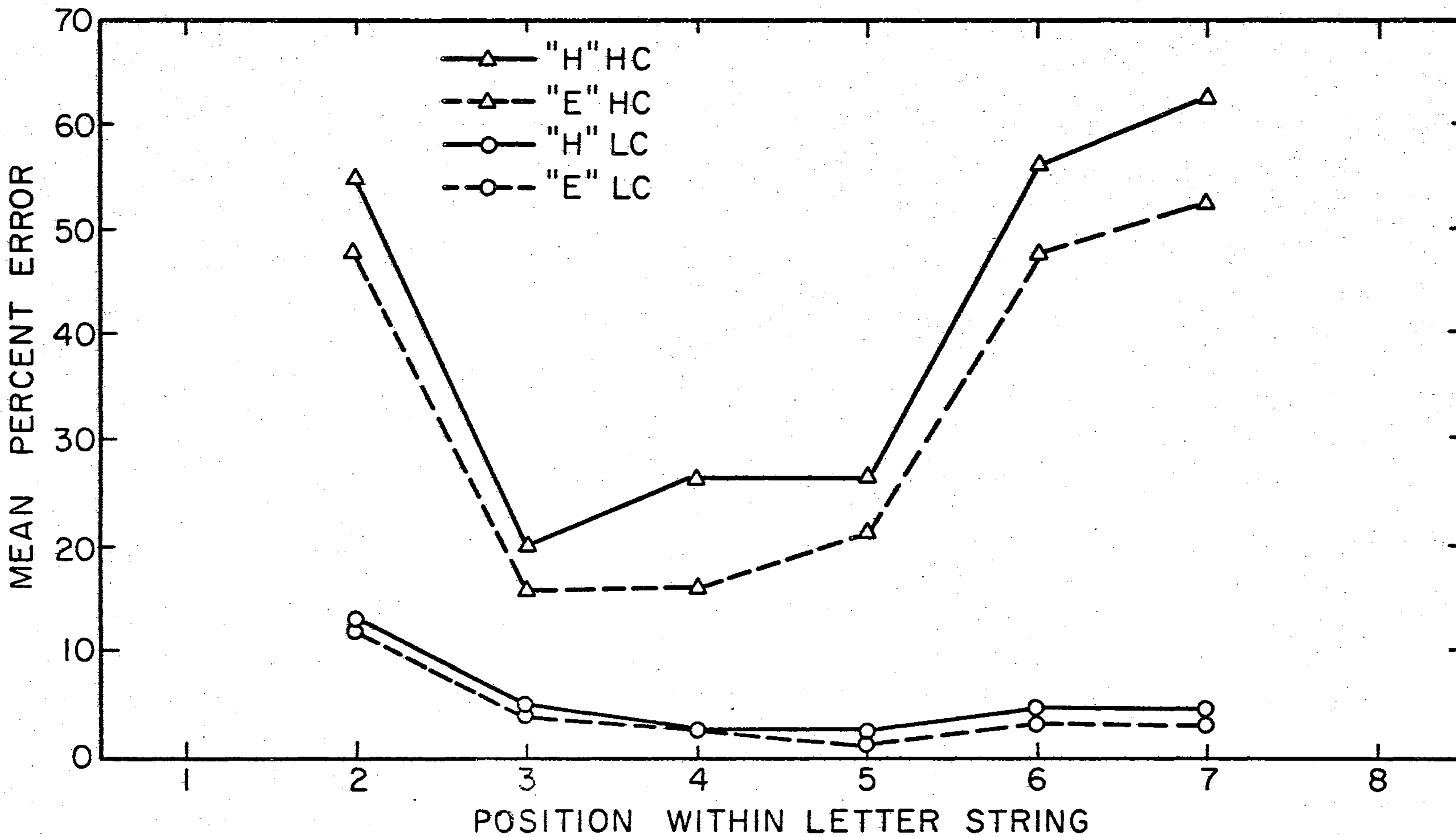

Figure 14. A Comparison of Scoring Criteria (Easy vs. Hard) for Missed Target Errors at V1

different field velocities upon scanning behavior. An analysis of the various measures of performance failed to reveal any significant differences attributable to different target-field velocities. The absence of the differences may be a result of the combination of stimulus exposure time and angular target velocity utilized in this experiment. From the results of Burg and Hulbert, (1961) the minimum angular velocity of target stimuli used in their DVA test were 20 deg/sec. with a one second exposure duration. Therefore, the velocities in this experiment could have been so slow that the differential effects were nullified. A second factor that must be considered is exposure time.

A question arises as to which measure should form the bases for determining exposure time in a task of this type. As shown in Table X, the time that the intact stimulus line was visible was equated for V1 and V2. However, the stimulus strings were exposed moving into view from behind one edge of the viewing aperture and disappearing behind the other edge. This exposure time for V1 and V2 was 562.5 msec. and 312.5 msec. respectively.

Recent research by Hochberg (1968), Parks (1965, 1968), and Haber and Nathanson (1968), indicates that the appropriate base for exposure time would be the duration that any portion of a stimulus was visible. Their findings, using similar methods of stimulus presentation indicate that a great deal of information can be extracted from even a subtotal presentation of a stimulus item. Thus, for tasks involving serial exposure of a stimulus (regardless of the rapidity of the "unveiling" time) might necessitate beginning the exposure time with the first instant that a portion of the stimulus is visible.

In conjunction with the question posed above, is one raised by

Sperling (1960). He raised a question as to how long was information available in brief tachistoscopic exposures of stimuli. He found evidence that after stimulus precentation had ceased, the Ss were still capable of extracting stimulus information from a type of stored visual image. He called this mnemonic process the Visual Information System (VIS). This was a very short term memory system which lasts for a fraction of a second after the stimulus has been removed.

The exposure times that Sperling used were durations from .015 to .500 seconds and this range well encompased the exposure times used in both Experiment I and in the present study. The implication of these findings would suggest that scanning behavior is primarily a function of the time available for processing stimulus information, rather than limited to the interval of time that the stimulus is physically presented to the S.

This time span would begin with any partial exposure of the stimulus and terminate when the briefly stored visual image has faded.

In this experiment the relatively long time span available for extracting stimulus information, in conjunction with the particular angular velocities of the stimuli, could have masked any effects which might have been attributed to changes in velocity.

The relationship of missed target errors with the levels of visual confusion exhibited not only a quantitative but qualitative interrelatedness. As in Experiment I, the HC condition produced a "V" shape patterning of errors in which there were a larger number of misses in the lateral string positions. The LC condition demonstrated an equivalency of errors across the target positions. These findings would indicate that perception of a target in this type of visual search task is more sensitive to the background configuration than to the particular mode in which it is displayed.

The concept of Mackworth's visual noise and how the relative level of noise is associated with the level of visual confusion would again explain the apparent contraction of the useful visual field in this experimental search task. This is supported by Figure 10, which indicates that under a condition of low visual noise (LC) the useful field (error rate less than 50%) is at least the width of the six target positions. Under a higher noise level (HC), the visual system is overloaded and thus contracts to a width of four target positions, in order to process a smaller amount of information with greater accuracy.

False alarm (F/A) errors were more easily interpretable in this study than in the first experiment. There was a positive correlation between the level of visual confusion and the F/A error rate. It is interesting to note that there did not appear to be any differential patterning of positional errors in relation to a specific level of visual confusion. Apparently there is little correlation of error rate with target position, thus, indicating that this type performance measure is only grossly affected by changes in confusion level. The string positions 1 and 8 were included in the analysis to demonstrate that even though a target never occurred in these positions (without the S given knowledge of it) the Ss would infrequently mark these positions as containing targets. Thus, again emphasizing how a high confusion level can effect the total stimulus in producing F/A.

In summary it may be concluded, as in Experiment I, that the confusion level in a visual search task affects performance more strongly than the other variables investigated. The second factor, and probably the one with more far reaching implications, is how a high target/

background confusion can reduce the size of the useful field and can create a functional type of tunnel vision. Another thing concerning this contraction of the field is that it is relatively instantaneous in that the ordering of HC and LC stimulus strings was randomized and from trial to trial any ordering of confusion was probable. From the results it can be seen that this field must contract on initial exposure of a stimulus string and immediately expand for a LC string. Hence, it is unlikely that there were carry-over effects from trial to trial in terms of Ss having a particular viewing strategy.

CHAPTER IV

EXPERIMENT III: VISUAL SEARCH BEHAVIOR AS A FUNCTION OF STIMULUS ORIENTATION AND DIRECTION OF FIELD MOVEMENT

Differences in visual search behavior that are attributable to stimulus orientation have usually been measured as a function of scanning speed. Brown and Strongman's (1966), paper is representative, both in methodology and experimental findings, of research dealing with the study of stimulus orientation and its effects upon visual search behavior using a static field. They reported that a horizontal string (HS) of letters was scanned more quickly than a correspondingly arrayed vertical string (VS) of letters. They attributed the difference in scanning speed to the factor of stimulus orientation rather than to characteristics of letter arrangement and reading skills.

This present experiment was designed to investigate differences in stimulus orientation and the effect of different directions of movement for each of the stimulus string orientations.

Stimulus string movement was classified as involving either a "typical" or an "atypical" direction. The rationale for this classification was based upon the sequential order of reading written English. If one considers the relative movement and direction of stimulus material, assuming no eye movement, necessary to accomplish the sequential presentation of material to be read; then reading involves the stimulus material moving in a South to North (Bottom to Top) direction for processing lines of words sequentially. An East to West direction is required for scanning words in a proper sequence within a given line, eg., the reader tracks from West to East; therefore the appropriate motion, with the reader stationary, of the stimulus material is East to West.

For a HS letter string moving in a South to North direction and for a VS letter string moving in an East to West direction would constitute a "Typical" direction pattern. North to South and West to East directions of movement for the HS and VS strings, respectively, were classified as "Atypical" directions.

Method

Stimulus Materials: The same pool of capital letters as used in Experiment II were used as stimuli. An eight letter string size was again utilized, and these were arrayed on both a horizontal and vertical axis. For each orientation, HS and VS, lists were composed of an equal number of HC and LC confusion letter strings.

Apparatus: The same apparatus was used as in Experiment II with the following modifications. Letter strings moved at a constant velocity of 0.66 in/sec. through the viewing apertures. Two apertures (0.25 x 2/0 in,) were used, one for the display of HS letter strings. The second aperture was oriented in a North-South direction to display the moving VS letter strings.

Experimental Variables: 1) and 2) Orientation and direction of string movement. HS letter strings moved in both a North to South and South to North direction through a horizontally orientated viewing aperture. VS letter strings moved in both an East to West and West to East direction through a viewing aperture oriented on a vertical axis.

3) Target/background confusion. The same letter lists (HC,LC) as in Experiment I were used, each arrayed in both a line and column

arrangement.

4) Letter string position. As in the previous experiment, target letters occupied string positions two through seven and F/A were scored on all eight string positions.

Experimental Design: The design of this experiment was a 2x2x2x6 split plot factorial design. The first factor, stimulus orientation, was a Between-S measure, and the remaining three factors were Within-S variables.

Stimulus Presentation and Recording: This study employed the same manner of trial presentation and recording of responses as in Experiment II.

Procedure: The procedure followed was the same as in the preceeding experiment.

Subjects: Twenty introductory psychology students at Oklahoma State University participated as Ss. Each of the two groups were composed of five male and five female Ss. Group assignment and sequence of experimental conditions was made according to a randomization procedure. These Ss were tested for normal near vision on the same FAA form #2917.

Scoring of Responses: Responses were scored in the same manner as in the previous two experiments.

Results

Performance in this visual search task was measured on both missed target errors and F/A. The data were analyzed on both scoring criteria as in previous experiments. Criterion "H" scoring was analyzed and presented in this section, while the analysis of criterion "E" scores is contained in Appendix C. Reference to this source may be made if the reader desires to make comparisons between the two scowing methods.

The experimental task performance on this visual search experiment is summarized in Table XVI. A comparison of the data in this table and that of Table I in Experiment II yields comparable error rates with the exception of missed target errors.

Missed Target Errors: Figure 15 illustrates a comparison of the average performance of Ss relative to the two stimulus orientations. These values were derived by summing and averaging over the two directions of movement for each confusion level and for each orientation. From a cursory inspection of these performance curves, it is apparent that targets were detected with greater accuracy in a HS string than in a VS string. The effect of visual confusion on target detection is again demonstrated and the relationship between HC and LC conditions remains that of a semi-vee shape and a relatively straight line, respectively.

Figures 16 and 17, graphically describe the relative difference between directions of field movement for the HS and VS orientations.

In Figure 17 it may be noticed that there is relatively little difference in error rates attributable to the two movement patterns in either the LC or HC condition for an HS letter string. Differential effects of movement patterns is more clearly illustrated in Figure 17 which depicts performance on a vertically oriented letter string. In this there is again relative equal performance under a LC condition; however, under the HC condition it is quite apparent that the atypical (left to right) direction produces a higher rate of misses across all positions. Comparing the performance among the two orientations for the HC condition it would appear that the central portions of the letter string are more affected by directional variables than are the lateral target positions.

TABLE XVI

A SYNOPSIS OF EXPERIMENTAL TASK PERFORMANCE

Total number of stimulus lines presented.	11,520
Number of lines containing an error	2,365
Percent total error	20.5%
Number of lines containing a target letter.	5,760
Number of lines scored as misses.	1,754
Percent misses.	38.1%
Number of lines not containing a target letter.	5,760
Number of lines scored as false alarms.	611
Percent F/A	10.6%
Number of (LC) target lines	2,880
Number of misses.	351
Percent misses.	12.1%
Number of (HC) target lines	2,880
Number of misses.	1,403
Percent misses.	48.7%
Number of (LC) non-target lines	2,880
Number of F/A	192
Percent F/A	6.6%
Number of (HC) non-target lines	2,880
Number of F/A	419
Percent F/A	14.5%

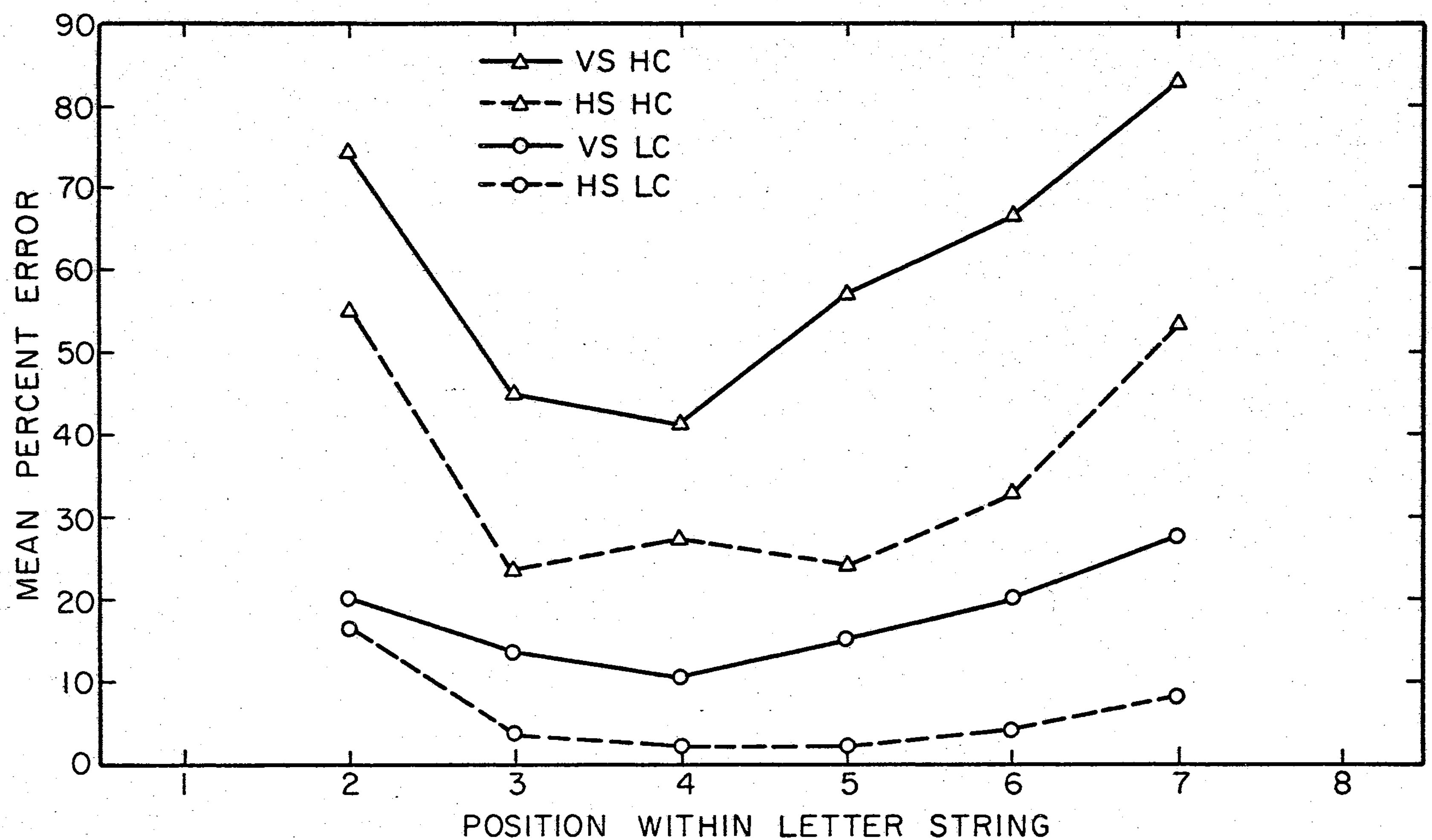

Figure 15. Missed Target Errors for Orientation and Confusion Level as a Function of String Position

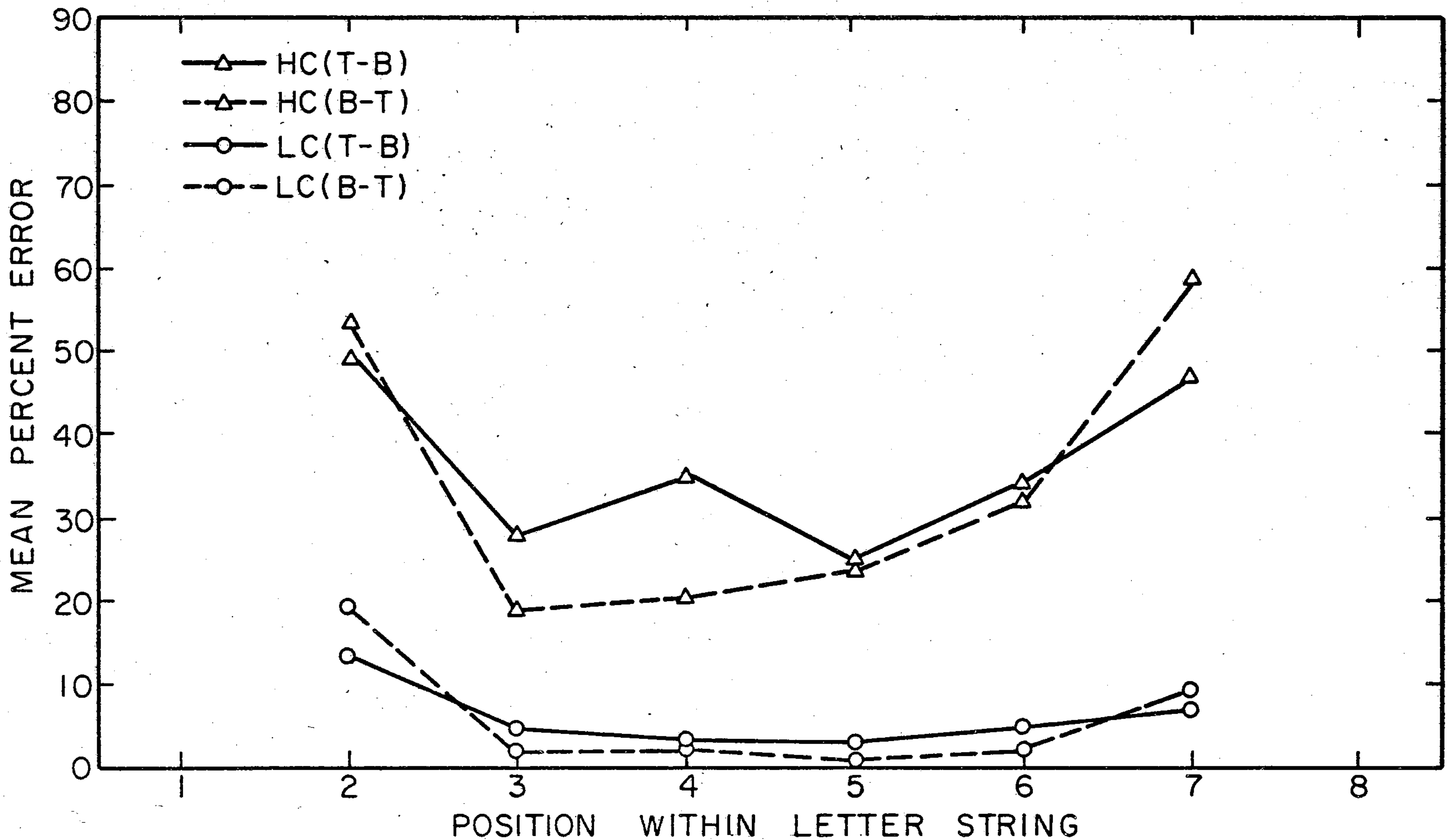

Figure 16. Missed Target Errors as a Function of Direction of String Movement for a Horizontal Array of Stimulus Letters

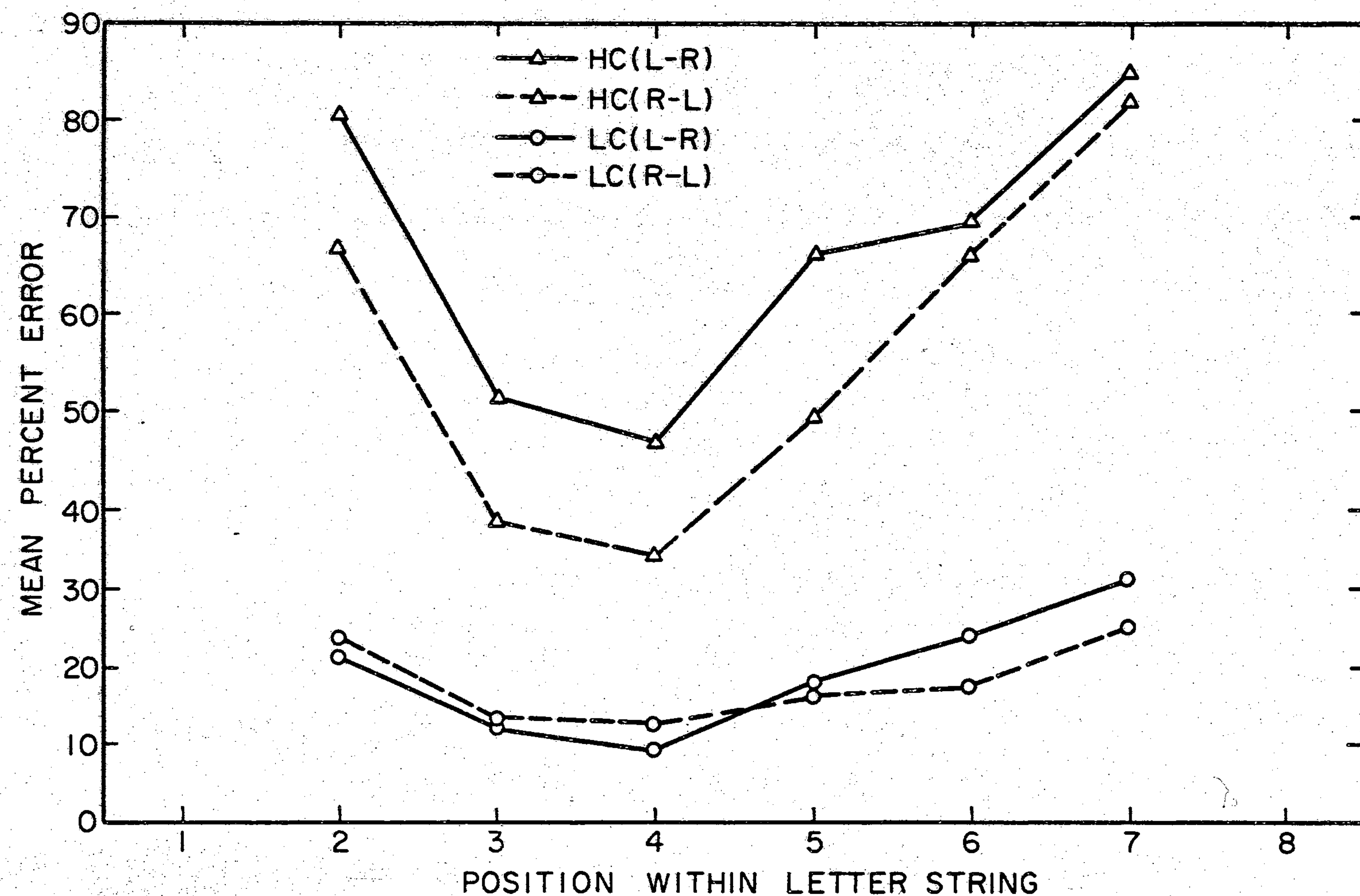

Figure 17. Missed-Target Errors as a Function of Direction of String Movement for a Vertical Array of Stimulus Letters

The performance measured by missed-target errors was analyzed by an AOV procedure and the results are summarized in Table XVII. The results of this analysis revealed that all four factors were significant as well as four of the two factor interactions. These interactions were in turn analyzed for simple effects.

The interaction of string orientation with confusion level is summarized in Table XVIII. The results indicated that under the LC condition there were no significant differences in error rate between the HS and VS string orientations. However, under HC (high confusion) there was a highly significant difference in the error rate and that there were more errors as in Experiment I for the VS orientation.

The simple effects of the stimulus orientation with target position interaction were analyzed and the summary of the data is presented in Table XIX and graphically displayed in Figure 18. An interesting finding of the simple effects was, even though the curves were statistically different, there was a close similarity of error patterning between the two orientations, with the VS producing the higher error rate.

The third interaction analyzed was direction of movement and confusion level. The summary of this AOV procedure for testing of simple effects is contained in Table XX. The results indicated that under the LC condition there were no significant differences attributable to the two directions of string movement. However, with a high level of target/background confusability, the directional movement of the letter strings did produce a significant difference ($p < .01$) of error rates.

The last test of simple effects was made on the interaction of confusion level with target positions. The AOV summary is contained in Table XXI and the relationships displayed in Figure 19. The relationship between the HC and LC condition is again replicated as it has been

TABLE XVII

ANALYSIS OF VARIANCE FOR MISSED TARGET ERRORS

Source	df	SS	MS	F/Cal
Between Subjects	19	1439.57	75.77	
A (Orientation)	1	623.35	623.35	13.75**
Subj. W. Gps.	18	816.22	45.35	
Within Subjects	460	4541.67	9.87	
B (Movement)	1	19.60	19.60	5.04*
AB	1	14.35	14.35	3.69
B x Subj. W. Gps.	18	69.93	3.89	
C (Confusion)	1	2266.35	2266.35	171.95**
AC	1	84.17	84.17	6.39*
C x Subj. W. Gps.	18	237.19	13.18	
D (String Position)	5	555.34	111.07	24.20**
AD	5	59.89	11.98	2.61*
D x Subj. W. Gps.	90	412.66	4.59	
BC	1	13.00	13.00	5.33*
ABC	1	4.22	4.22	1.73
BC x Subj. W. Gps.	18	43.99	2.44	
BD	5	13.34	2.67	1.28
ABD	5	15.59	3.12	1.50
BD x Subj. W. Gps.	90	187.45	2.08	
CD	5	127.79	25.56	9.57**
ACD	5	11.27	2.25	0.84
CD x Subj. W. Gps.	90	240.49	2.67	
BCD	5	21.74	4.35	2.81*
ABCD	5	3.72	0.74	0.48
BCD x Subj. W. Gps.	90	139.59	1.55	
Total	479	5981.24		

** = $p < .01$
* = $p < .05$

TABLE XVIII

AOV SUMMARY OF SIMPLE EFFECTS FOR ORIENTATION AND CONFUSION LEVEL INTERACTION

Source	df	SS	MS	F/Cal
Orientation at				
LC	1	124.66	124.66	4.26
HC	1	582.81	582.81	19.91**
Error	18		29.27	
Visual Confusion at				
HS	1	738.51	738.51	56.03**
VS	1	1612.02	1612.02	122.31**
Error	18		13.18	

** = $p < .01$

TABLE XIX

AOV SUMMARY OF SIMPLE EFFECTS FOR ORIENTATION AND LETTER POSITION ON MISSED TARGET ERRORS

Source	df	SS	MS	F/Cal
Orientation at				
TP-2	1	51.20	51.20	4.50*
TP-3	1	68.45	68.45	6.01*
TP-4	1	35.12	35.12	3.09
TP-5	1	162.45	162.45	14.28**
TP-6	1	183.02	183.02	16.08**
TP-7	1	183.02	183.02	16.08**
Error	78		11.38	
String Position at				
HS	5	241.53	48.31	10.53**
VS	5	373.70	74.74	16.28**
Error	90		4.59	

** = $\underline{p} < .01$
* = $\underline{p} < .05$

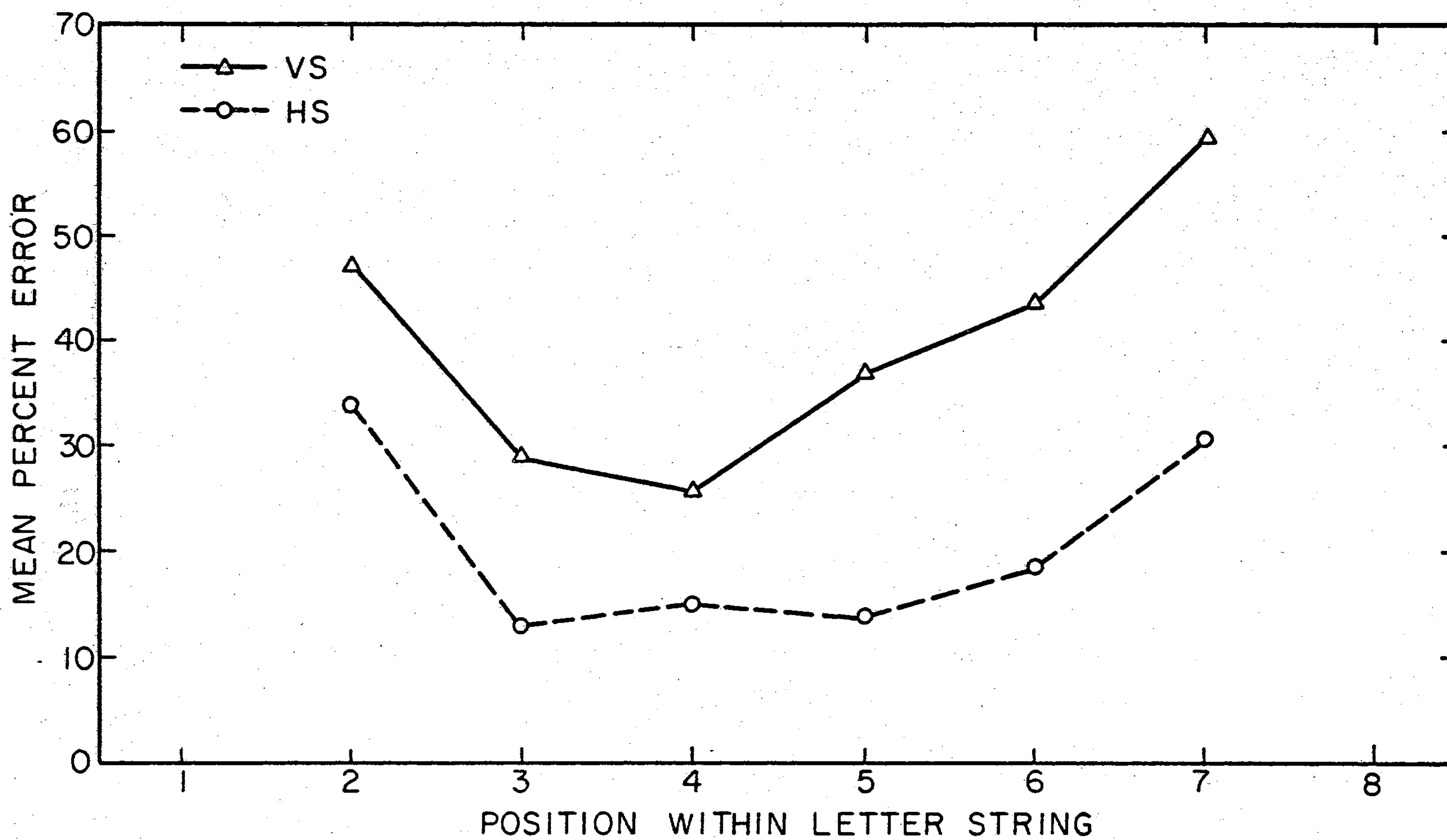

Figure 18. Illustration of Interaction Between String Orientation and Target Position

TABLE XX

AOV SUMMARY OF SIMPLE EFFECTS FOR MOVEMENT AND CONFUSION INTERACTION FOR MISSED TARGET ERRORS

Source	df	SS	MS	F/Cal
Movement at				
LC	1	0.34	0.34	0.11
HC	1	32.26	32.26	10.18**
Error	18		3.17	
Visual Confusion at				
Typical	1	968.01	968.01	123.94**
Atypical	1	1311.34	1311.34	167.91**
Error	18		7.81	

** = $p < .01$

TABLE XXI

AOV SUMMARY OF SIMPLE EFFECTS FOR CONFUSION AND TARGET POSITION INTERACTION

Source	df	SS	MS	F/Cal
Visual Confusion at				
TP-2	1	561.80	561.80	127.10**
TP-3	1	192.20	192.20	43.48**
TP-4	1	227.82	227.82	51.54**
TP-5	1	288.80	288.80	65.34**
TP-6	1	409.52	409.52	92.65*
TP-7	1	714.02	714.02	161.54**
Error	18		4.42	
Target Position at				
LC	5	78.44	15.69	4.32**
HC	5	604.68	120.94	33.32**
Error	90		3.63	

** = $p < .01$

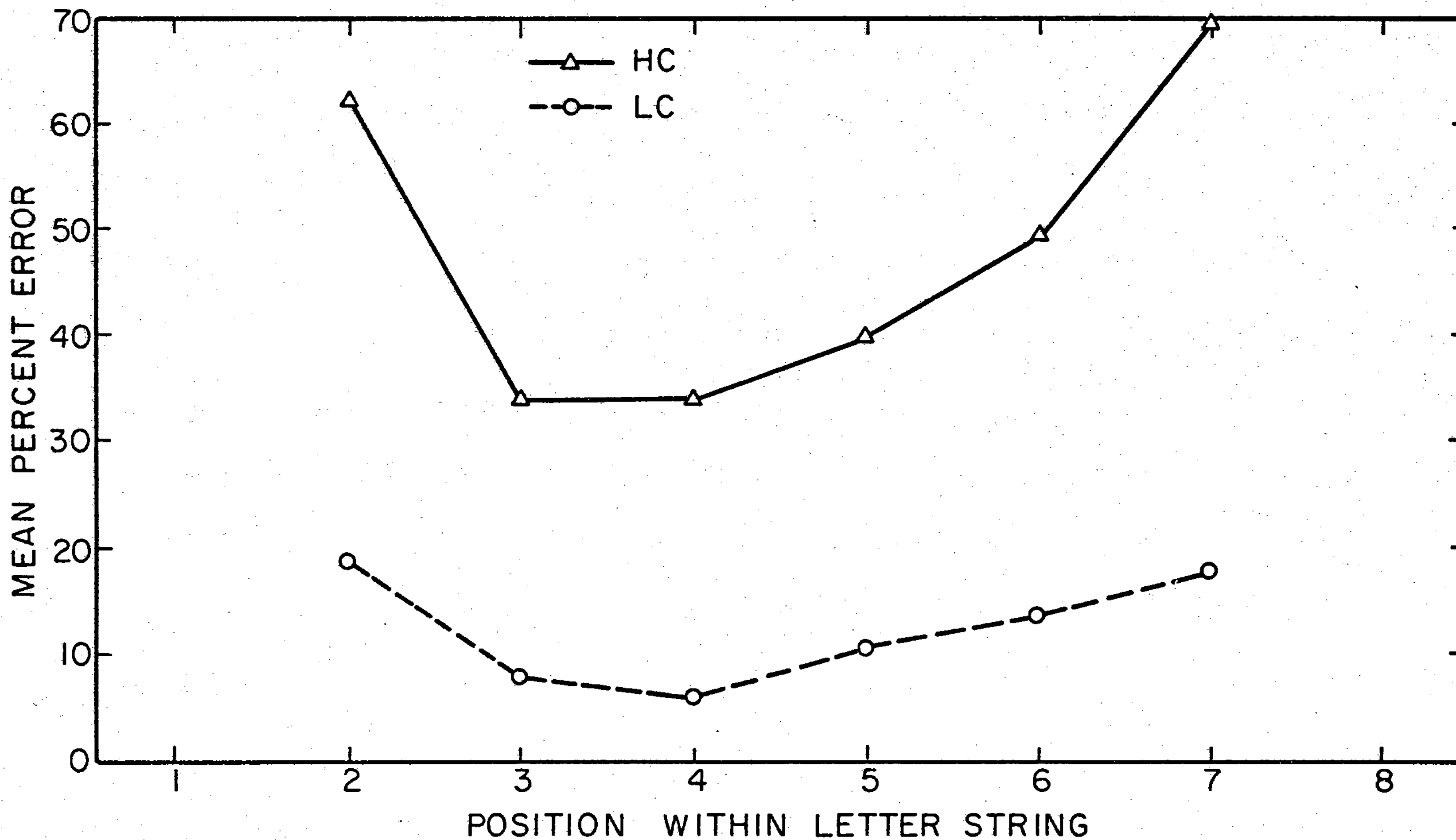

Figure 19. Illustration of Interaction Between Confusion Level and Target Position

in the two previous experiments.

False Alarm Errors: The total number of F/A errors per string position for both the HS and VS orientations are displayed in Figures 20 and 21. These values were derived using criterion "H" as a scoring measure.

It is noteworthy that for horizontally presented stimuli the error rate for combinations of visual confusion and string movement is relatively stable across all cell positions of the stimulus string. The vertical array of letter strings presents a comparable relationship with the exception that the typical (right to left) movement was associated with a notable increase in errors among string positions 2,3, and 4 under high visual confusion. The major aspect of these curves is the difference in the F/A rate between the two levels of confusion.

An AOV of this data is summarized in Table XXII. The main effects of stimulus orientation and direction of movement were nonsignificant at the .05 level; however, the interaction of stimulus orientation and string position was significant. This interaction was analyzed for simple effects and the results are contained in Table XXIII. The important findings of this analysis was that the positions 2,3, and 4 exhibited a higher error rate for the VS orientation than for the HS string, while the remaining cell positions were not statistically different ($p < .05$).

As depicted in Figure 22, the error rate for the HS array was relatively stable across the target positions, (2-7), with the major differences being the contrast of string positions 1,8 with 2 and 7. The VS string displayed a higher overall error rate and a larger number of F/A for the letter cells 2,3,and 4, when compared to cell positions 5,6, and 7.

Table XXIV contains the last interaction investigated, that of

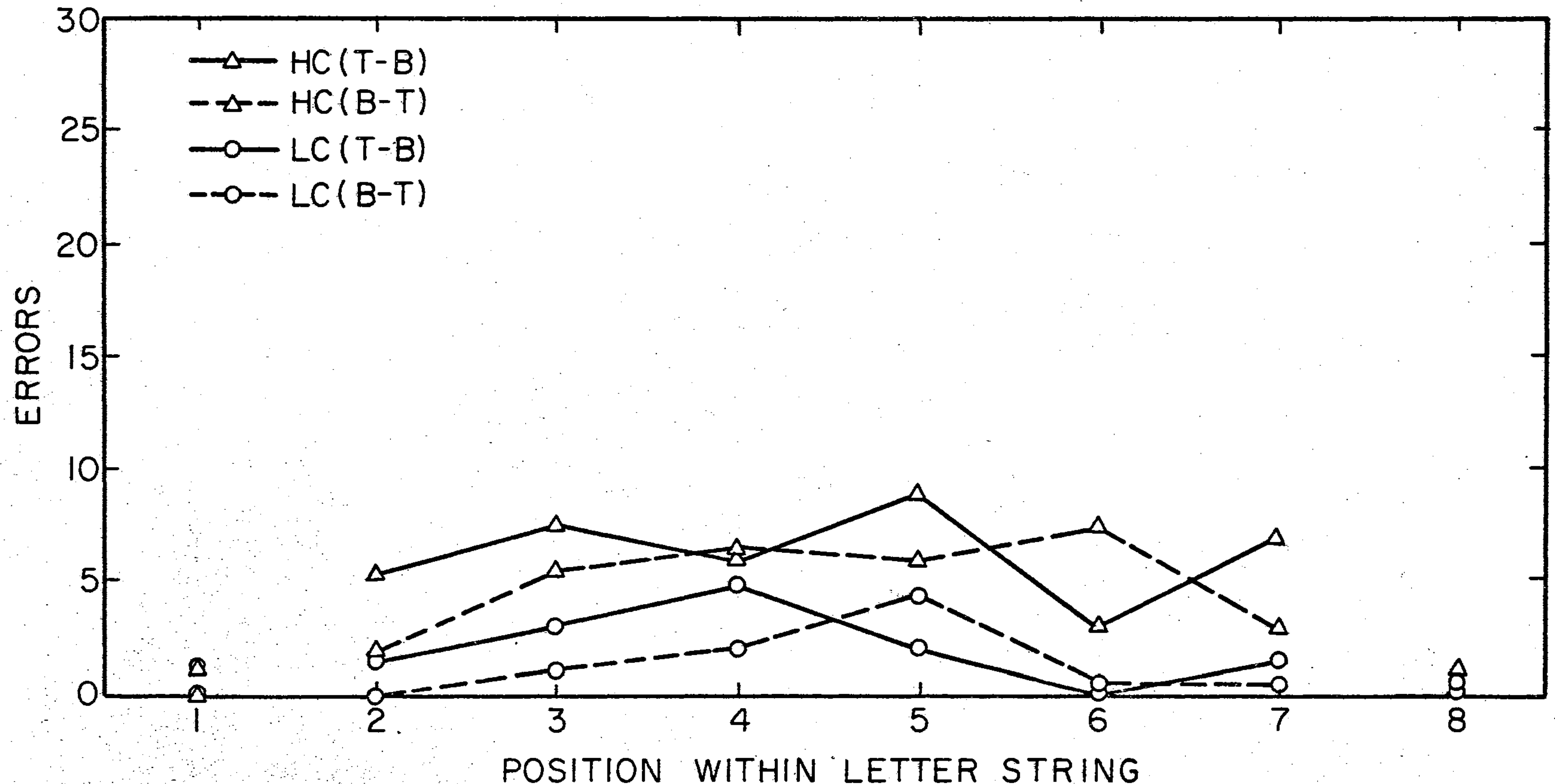

Figure 20. False Alarm Errors for Movement Direction on a Horizontal String

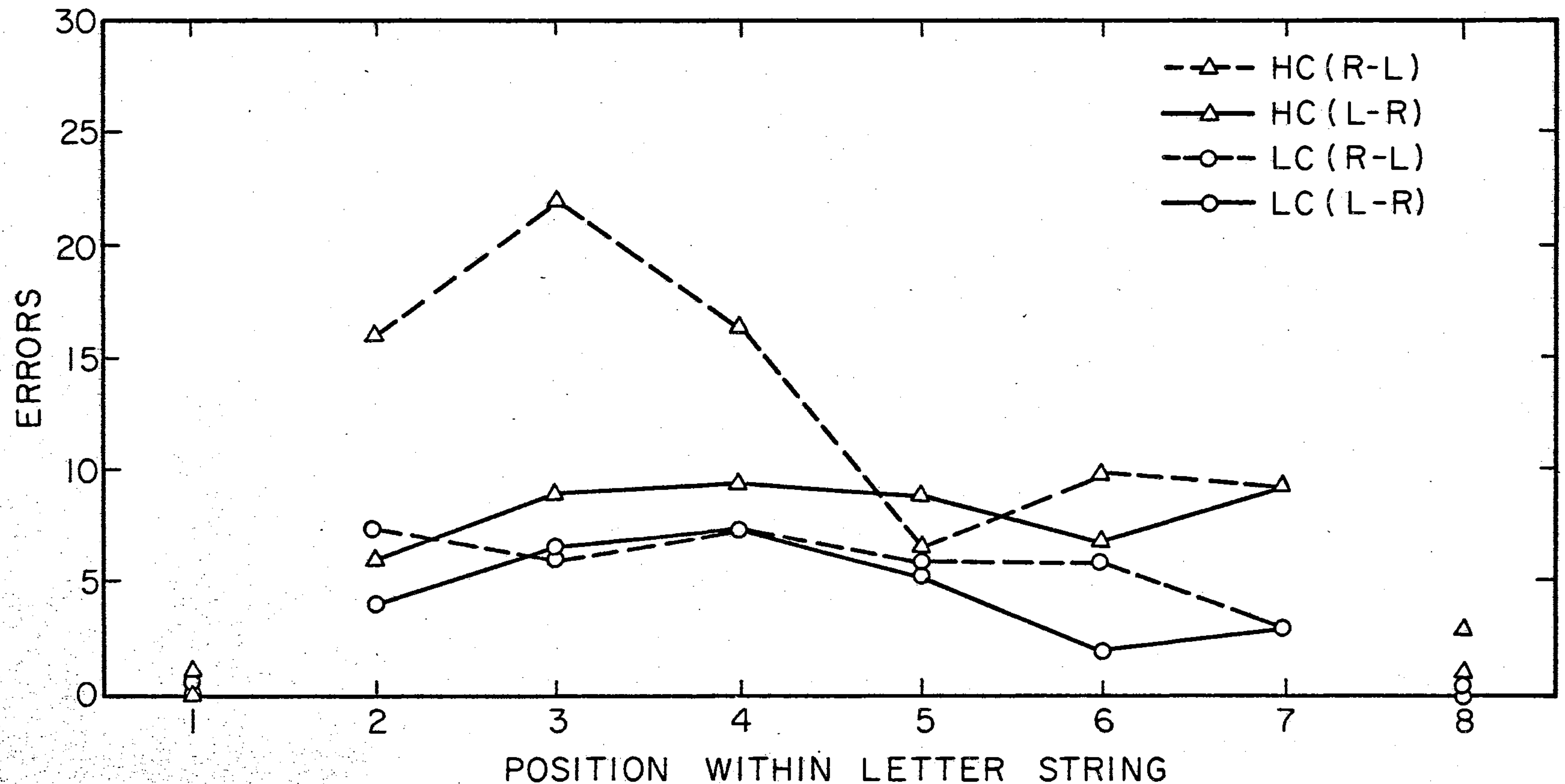

Figure 21. False Alarm Errors for Movement Direction on a Vertical String

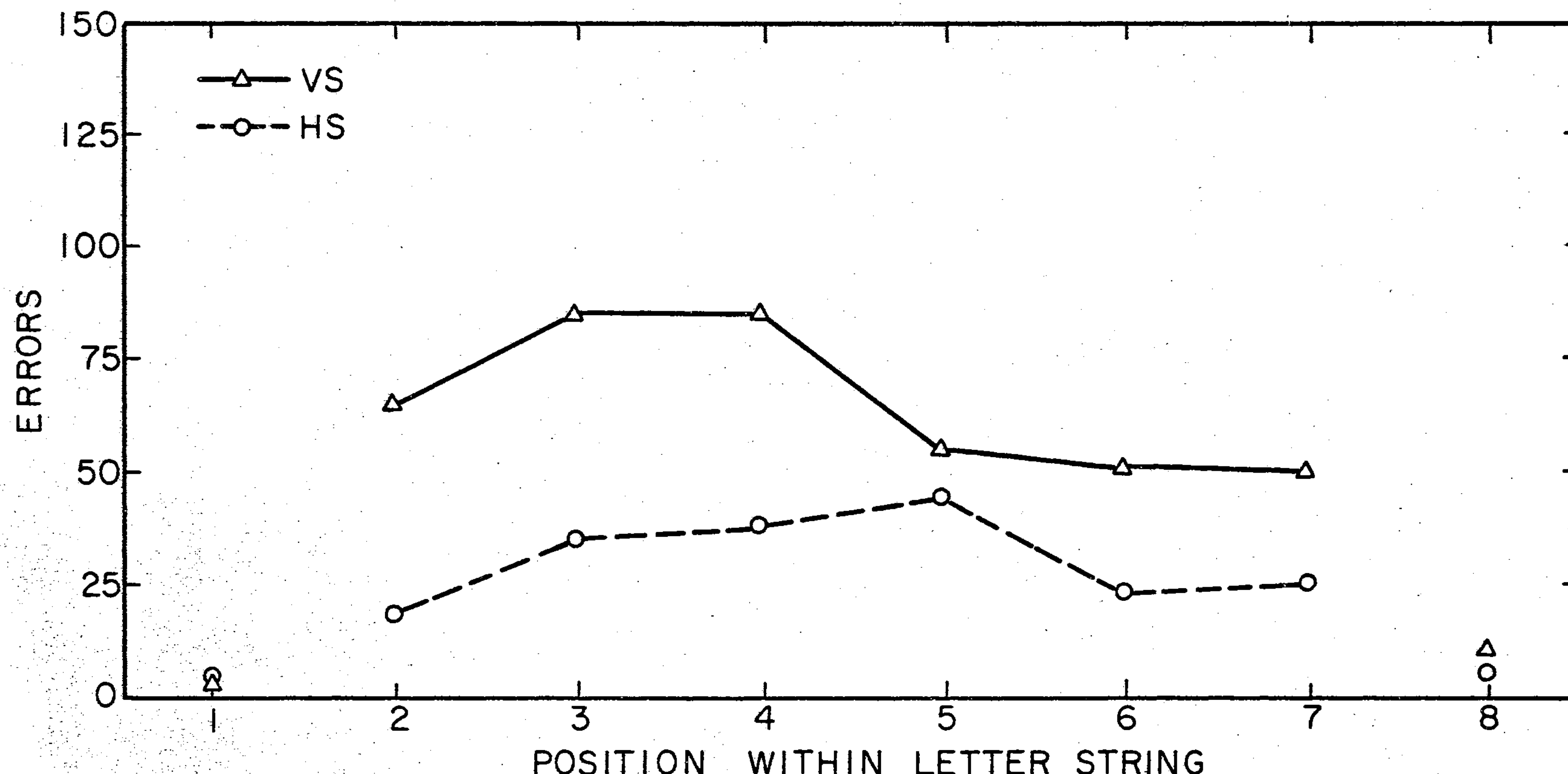

Figure 22. Illustration of Interaction Between Stimulus Orientation and String Position

TABLE XXII

ANALYSIS OF VARIANCE SUMMARY TABLE FOR FALSE ALARM ERRORS

Source	df	SS	MS	F/Cal
Between Subjects	19	544.91	28.67	
A (Orientation)	1	72.23	72.23	2.75
Subj. W. Gps.	18	472.68	26.26	
Within Subjects	620	1734.34	2.80	
B (Movement)	1	5.08	5.08	0.83
AB	1	18.56	18.56	3.04
B x Subj. W. Gps.	18	108.26	6.10	
C (Confusion)	1	90.75	90.75	4.69*
AC	1	3.75	3.75	0.19
C x Subj. W. Gps.	18	348.15	19.34	
D (String Position)	7	163.36	23.34	10.28*
AD	7	37.44	5.35	2.36*
D x Subj. W. Gps.	126	285.79	2.27	
BC	1	2.89	2.89	0.59
ABC	1	4.73	4.73	0.97
BC x Subj. W. Gps.	18	87.54	4.86	
BD	7	13.79	1.97	1.95
ABD	7	19.25	2.75	2.72*
BD x Subj. W. Gps.	126	127.31	1.01	
CD	7	28.06	4.01	2.11*
ACD	7	7.71	1.10	0.58
CD x Subj. W. Gps.	126	239.82	1.90	
BCD	7	15.77	2.25	2.42*
ABCD	7	8.99	1.28	1.37
BCD x Subj. W. Gps.	126	117.34	0.93	
Total	639	2279.25		

* = $\underline{p} < .05$

TABLE XXIII

AOV SUMMARY OF SIMPLE EFFECTS FOR STIMULUS ORIENTATION AND LETTER STRING INTERACTION ON FALSE ALARM ERRORS

Source	df	SS	MS	F/Cal
Orientation at				
TP-1	1	0.012	0.012	0.002
TP-2	1	30.12	30.12	5.72*
TP-3	1	32.52	32.52	6.17*
TP-4	1	26.45	26.45	5.02*
TP-5	1	1.52	1.52	0.29
TP-6	1	10.52	10.52	2.00
TP-7	1	8.45	8.45	1.60
TP-8	1	0.10	0.10	0.019
Error	113		5.27	
Position at				
HS	7	51.40	7.34	3.23**
VS	7	164.4	23.49	10.35**
Error	126		2.27	

** = $p < .01$
* = $p < .05$

TABLE XXIV

AOV SUMMARY OF SIMPLE EFFECTS FOR CONFUSION AND LETTER STRING POSITION INTERACTION ON FALSE ALARM ERRORS

Source	df	SS	MS	F/Cal
Visual Confusion at				
TP-1	1	0.01	0.01	0.0009
TP-2	1	13.62	13.62	1.28
TP-3	1	40.62	40.62	3.82
TP-4	1	14.45	14.45	1.36
TP-5	1	7.82	7.82	0.74
TP-6	1	19.02	19.02	1.79
TP-7	1	22.05	22.05	2.08
TP-8	1	1.25	1.25	0.12
Error	72		10.62	
String Position at				
LC	7	39.98	5.71	2.93
HC	7	151.45	21.64	11.10*
Error	126		1.95	

* = $p < .05$

confusion level with letter string position. The simple effects of confusion level with better string position. The simple effects of confusion level with the individual cell positions were nonsignificant ($p < .01$) across all eight cell positions. This finding is aberrant when compared with the same interaction as occurred in Experiment II, where there were significantly different error rates for the two levels of confusion. The only significant contrasts of cell position and confusion level occurred under the HC condition and this is primarily due to the large number of F/A that occurred on a VS string in cell positions 2,3, and 4.

Discussion

The relationship between string orientation and effectiveness of scanning behavior as determined in this study using a dynamic field, is in agreement with the results of Brown and Strongman (1966) who used static fields. Horizontal letter strings were scanned with greater accuracy than the VS arrays under both a HC and LC condition.

The second major variable, direction of stimulus movement, appeared to have inconsequential effects on target detection except when it was conducted under a HC condition. Under these conditions, the "typical" directions of stimulus movement (South to North for HS; East to West for VS) yielded lower error rates for the various target positions. The largest relative difference between directional effects occurred with a VS letter string. The interpretation of this phenomenon of movement patterns is difficult in that one cannot eliminate the possible biasing effects of experience gained in reading written English from the two directions of movement. Thus, reading experience would tend to make the "typical" movement directions less perceptually disturbing and produce a lower error rate.

Performance measured by F/A errors revealed further difference in the ability of scanning a VS and HS stimulus array. Direction movement of the stimulus strings did not produce a corresponding difference in error rate.

In summary this experiment again supports the theoretical basis for explaining visual search behavior from a basis of "visual noise" as proposed by Mackworth. Not only is there a difference in the width of the useful field in the HC and LC conditions, any other variable introduced into the scanning task that increases the load upon the S also results in an elevation of the error rates among the lateral target positions. The net result of this is that the slope of the Vee shape error curve steepens and the effective field size is further reduced as evidenced by the level and shape of the HC condition error curves for a HS and VS string. Thus, one may propose that the differences in target detectability attributable to stimulus orientation are a result of the physiological limitations of the visual system itself and may be considered as a source of "internal noise". Thus external or internal introduction of noise into the visual system creates limitations on the channel capacity and efficiency of processing visual stimuli.

CHAPTER V

SUMMARY AND CONCLUSION

The purpose of this thesis was to investigate visual search behavior in a dynamic field. The experimental task required the Ss to identify the presence or absence of a target letter among an array of other background letters. Performance was evaluated on the basis of the number and type of errors committed during the task. Three experiments were conducted.

The first experiment, with a static field, provided normative data on several variables which then could be compared to results obtained using a moving display of stimulus material. The second experiment was primarily concerned with the effect of different field velocities upon scanning behavior. The last experiment investigated the effect of stimulus orientation and direction of stimulus movement upon target detection.

Errors were classified in signal detection terminology as being either misses or false alarms. Missed target errors proved to be the most sensitive measure in reflecting changes of the experimental variables. These changes in search behavior were both qualitative and quantitative in nature. False alarm errors reflected what were considered to be only gross changes in search behavior and were usually sensitive to changes in visual search behavior resulting from variables in the level of visual confusion.

The major findings of this paper were as follows. 1) In contrasting visual search behavior in a static and dynamic field, it was found that there were many common characteristics of performance between the two field conditions. Response to various stimulus configurations were qualitatively similar in that each exhibited a common function of relating errors to target positions within the stimulus string.

2) Many of the variables involved in normal scanning behavior such as scanning time, direction of stimulus movement, and stimulus velocity were effective in creating differential performance levels only under a high level of visual confusion. This suggests that search behavior is quite flexible in responding to varying conditions as long as the task itself is not conducted under a great deal of complexity. Visual confusion of target and background proved to have the greatest influence on the efficiency and characteristics of target identification in the various tasks.

3) A distinct and common patterning of missed target errors occurred between the two levels of visual confusion among the three experiments. Under a low level of target/background confusion, targets could be detected with approximately equal precision across all target positions of the stimulus strings. This led to a rather flat type error curve with minor fluctuations of error level between adjacent cell errors. However, under high visual confusion, the error rate over the target positions was distributed in a unique manner. The central target positions were scanned more accurately than the lateral positions. The data plot of these errors resulted in a semi-vee shaped curve which is opposite in shape to the usual serial position curves reported in studies of tasks concerned with visual span.

It is assumed that the performance measured in this study reflects primarily perceptual factors in that the experimental tasks were constructed to minimize the mnemonic and stimulus encoding load upon the Ss. The differences in the shape of the error curves in this paper and those previously cited by Harcum (1967) is attributed to the fact that Harcum's experimental task placed greater emphasis upon stimulus encoding and mnemonic processes. Therefore, the data suggest that experiments on the letter span might better be conceptualized as memory studies than as perceptual studies (Crovitz, 1965).

4) The concept put forth by Mackworth (1965), that the surrounding background of letters in a target string function as a noise factor which limits the size of the useful visual field, most adequately accounts for the data obtained in this paper. With a low visual confusion, or low noise condition, the six target positions could be scanned with approximately equal precision. When searching for the same target letter in a high noise condition, the useful field contracted to a width of three or four letters, as demonstrated by an excessive error rate among the lateral target positions. The error rate for these positions climbed to a level that the probability of detecting a target letter was much lower than a chance level. From the shape of these error gradients it would appear that the stimulus string is scanned from the center of the string outwards in both directions.

The experiments conducted in this dissertation suggest several future avenues for investigating visual search behavior. One of the most promising areas would appear to be a study of the trade-off between visual confusion and scanning time. A comprehensive study of this could possibly integrate scanning time, processing rate of the individual stimulus components and visual confusion variables as to the role they play in visual search behavior.

In summary it would appear that the visual system is limited in capacity for both the quantity and quality of the stimulus items to be presented. As this system nears full capacity, introduction of additional perceptual complexities lead to significant decrements in the facility of search behavior. Thus, search behavior appears to be a function primarily of where, and under what conditions the search is conducted rather than what the target is and its characteristics.

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A P P E N D I C E S

APPENDIX A

INSTRUCTIONS FOR EXPERIMENT I

This experiment is concerned with how accurately one can identify the presence or absence of a given letter when it is visible for a short duration and grouped among other letters. Your task in this study will be to correctly determine if a certain letter is present among a string of other letters.

If this letter is present, you will also be required to record its relative position within the letter string on your answer sheet. The specific letter you are to identify is designated as the "Target" or the target letter. Letter strings will be presented on both a vertical and horizontal axis as now shown on the display. (E projects both a horizontal and vertical letter string to illustrate).

Your answer sheet is arranged in the same orientation as the letter strings will appear. Each letter string contains eight letters and the positions of these letters are represented by the spaces on your answer sheet. When you see a target letter in a string, mark its corresponding position on the answer sheet as it appears relative to the other letters in the letter string. If you cannot mark its exact location as it appeared; estimate its position within the string as closely as possible. Remember you are not concerned with the identity of the other letters. You only have to determine the presence or absence of the target letter.

If the letter string does not contain a target letter, draw a line through the trial number. Remember, not every trial will contain a target letter, and those which do contain a target are randomly ordered if you do not see a target letter for several trials or if several successive trials contain targets. The relative position of the target letter within the letter string varies randomly. In summary, not every line will contain a target, nor will the target letter appear in the same position within the line each time.

Please try to avoid guessing. Accuracy in determining the presence or absence of the target is important and the time that the letter strings are visible is short.

In this experiment you will have one of two target letters, "E" or "K" to identify over a series of trials. At the beginning of each series you will be told which letter will be the target letter.

Do you have any questions?

APPENDIX B

INSTRUCTIONS FOR EXPERIMENT II

This experiment is concerned with how accurately one can identify the presence or absence of a given letter when it is visible for a short duration and grouped among other letters. Your task in this study will be to correctly determine if a certain letter is present among a string of other letters.

If this letter is present, you will also be required to record its relative position within the letter string on your answer sheet. The specific letter you are to identify is designated as the "Target" or the target letter. Letter strings will be presented on a horizontal axis as now shown on the display. (E projects a horizontal letter string to illustrate).

Your answer sheet is arranged in the same orientation as the letter strings will appear. Each letter string contains eight letters and the positions of these letters are represented by the spaces on your answer sheet. When you see a target letter in a string, mark its corresponding position on the answer sheet as it appears relative to the other letters in the letter string. If you cannot mark its exact location as it appeared; estimate its position within the string as closely as possible. Remember you are not concerned with the identity of the other letters. You only have to determine the presence or absence of the target letter.

If the letter string does not contain a target letter, draw a line through the trial number. Remember, not every trial will contain a target letter, and those which do contain a target are randomly ordered over the series of trials. Therefore, do not become concerned if you do not see a target letter for several trials or if several successive trials contain targets. The relative position of the target letter within the letter string varies randomly. In summary, not every line will contain a target, nor will the target letter appear in the same position within the line each time.

Please try to avoid guessing. Accuracy in determining the presence or absence of the target is important and the time that the letter strings are visible is short.

In this experiment you will have one target letter, "K" to identify over a series of trials.

Do you have any questions?

TABLE XXV

ANALYSIS OF VARIANCE FOR MISSED TARGET ERRORS: CRITERION "E"

Source	df	SS	MS	F/Cal
Between Subjects	19	203.32	10.70	
A (Velocity)	1	4.27	4.27	0.39
Subj. W. Gps.	18	199.05	11.06	
Within Subjects	220	1820.66	8.28	
B (Confusion)	1	589.07	589.07	97.69**
AB	1	12.15	12.15	2.01
B x Subj. W. Gps.	18	108.45	6.03	
C (String Position)	5	343.18	68.64	17.74**
AC	5	35.53	7.11	1.84
C x Subj. W. Gps.	90	347.95	3.87	
BC	5	152.73	30.55	12.08**
ABC	5	4.25	0.85	0.34
BC x Subj. W. Gps.	90	227.35	2.53	
Total	239	2023.98		

* = $p < .05$
** = $p < .01$

TABLE XXVI

ANALYSIS OF VARIANCE SUMMARY TABLE FOR FALSE ALARM ERRORS: CRITERION "E"

Source	df	SS	MS	F/Cal
Between Subjects	19	110.810	5.832	
A (Velocity)	1	.003	.003	.0005
Subj. W. Gps.	18	110.807	6.156	
Within Subjects	300	576.437	1.921	
B (Confusion)	1	60.378	60.378	16.93**
AB	1	7.503	7.503	2.10
B x Subj. W. Gps.	18	64.182	3.566	
C (String Position)	7	61.622	8.803	5.59**
AC	7	8.772	1.253	0.80
C x Subj. W. Gps.	126	198.543	1.576	
BC	7	22.597	3.228	2.86**
ABC	7	10.672	1.525	1.35
BC x Subj. W. Gps.	126	142.168	1.128	
Total	319	687.247		

** = $p < .01$

APPENDIX C

INSTRUCTIONS FOR EXPERIMENT III

This experiment is concerned with how accurately one can identify the presence or absence of a given letter when it is visible for a short duration and grouped among other letters. Your task in this study will be to correctly determine if a certain letter is present among a string of other letters.

If this letter is present, you will also be required to record its relative position within the letter string on your answer sheet. The specific letter you are to identify is designated as the "Target" or the target letter. Letter strings will be presented on both a vertical and horizontal axis as now shown on the display. (_E_ exposes both a horizontal and vertical letter string to illustrate).

Your answer sheet is arranged in the same orientation as the letter strings will appear. Each letter string contains eight letters and the positions of these letters are represented by the spaces on your answer sheet. When you see a target letter in a string, mark its corresponding position on the answer sheet as it appears relative to the other letters in the letter string. If you cannot mark its exact location as it appeared; estimate its position within the string as closely as possible. Remember you are not concerned with the identity of the other letters. You only have to determine the presence or absence of the target letter.

If the letter string does not contain a target letter, draw a line through the trial number. Remember, not every trial will contain a target letter, and those which do contain a target are randomly ordered over the series of trials. Therefore, do not become concerned if you do not see a target letter for several trials or if several successive trials contain targets. The relative position of the target letter within the letter string varies randomly. In summary, not every line will contain a target, nor will the target letter appear in the same position within the line each time.

Please try to avoid guessing. Accuracy in determining the presence or absence of the target is important and the time that the letter strings are visible is short.

In this experiment you will have one target letter, "K" to identify over a series of trials.

Do you have any questions?

TABLE XXVII

ANALYSIS OF VARIANCE FOR MISSED TARGET ERRORS: CRITERION "E"

Source	df	SS	MS	F/Cal
Between Subjects	19	1264.44	66.55	
A (Orientation)	1	401.50	401.50	8.38**
Subj. W. Gps.	18	862.94	47.94	
Within Subjects	460	4269.82	9.28	
B (Movement)	1	33.60	33.60	12.09**
AB	1	32.55	32.55	11.71**
B x Subj. W. Gps.	18	50.06	2.78	
C (Confusion)	1	2046.00	2046.00	92.71**
AC	1	94.52	94.52	4.28
C x Subj. W. Gps.	18	397.19	22.07	
D (String Position)	5	468.12	93.62	27.54**
AD	5	39.79	7.96	2.34*
D x Subj. W. Gps.	90	306.14	3.40	
BC	1	13.67	13.67	3.61*
ABC	1	10.50	10.50	2.77
BC x Subj. W. Gps.	18	68.20	3.79	
BD	5	13.34	2.67	1.43
ABD	5	5.99	1.20	0.64
BD x Subj. W. Gps.	90	168.72	1.87	
CD	5	121.74	24.35	10.23**
ACD	5	6.72	1.34	0.56
CD x Subj. W. Gps.	90	214.09	2.38	
BCD	5	20.42	4.08	2.41*
ABCD	5	6.49	1.30	0.77
BCD x Subj. W. Gps.	90	151.97	1.69	
Total	479	5534.26		

* = $p < .05$
** = $p < .01$

TABLE XXVIII

ANALYSIS OF VARIANCE SUMMARY TABLE FOR FALSE ALARM ERRORS: CRITERION "E"

Source	df	SS	MS	F/Cal
Between Subjects	19	257.53	13.55	
A (Orientation)	1	17.23	17.23	1.29
Subj. W. Gps.	18	240.30	13.35	
Within Subjects	620	746.03	1.23	
B (Movement)	1	1.31	1.31	0.48
AB	1	7.44	7.44	2.71
B x Subj. W. Gps.	18	49.47	2.75	
C (Confusion)	1	52.33	52.33	5.65*
AC	1	4.73	4.73	0.51
C x Subj. W. Gps.	18	166.79	9.27	
D (String Position)	7	44.64	6.38	6.08**
AD	7	9.46	1.35	1.29
D x Subj. W. Gps.	126	131.68	1.05	
BC	1	2.38	2.38	0.85
ABC	1	1.50	1.50	0.54
BC x Subj. W. Gps.	18	50.21	2.79	
BD	7	3.92	0.56	1.27
ABD	7	8.90	1.27	2.89**
BD x Subj. W. Gps.	126	55.71	0.44	
CD	7	13.06	1.87	2.49*
ACD	7	4.36	0.62	0.83
CD x Subj. W. Gps.	126	94.49	0.75	
BCD	7	3.46	0.59	1.11
ABCD	7	2.54	0.36	0.82
BCD x Subj. W. Gps.	126	55.65	0.44	
Total	639	2279.25		

* = $p < .05$
** = $p < .01$

VITA

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