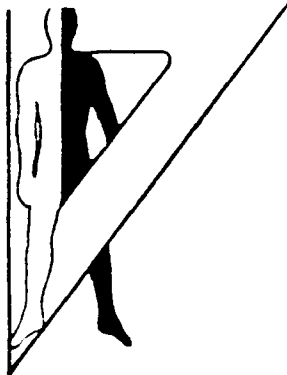


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PROGRAM "CLUSTER" - AN IDENTIFICATION OF
FIXATION CLUSTER CHARACTERISTICS

Ramakrishna S. Pillalamarri
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January 1992
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U.S. ARMY HUMAN ENGINEERING LABORATORY

Aberdeen Proving Ground, Maryland

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EXECUTIVE SUMMARY

Innovative software techniques to advance methods of analysis in eye movement research have not kept pace with the development of hardware for collecting the samples of eye position (Scinto & Barnette, 1986). Eye fixation and duration have been the primary measures focused upon to glean knowledge of subjects' performance while engaged in cognitive visual tasks. Program "cluster" was developed as a means of investigating the dynamics of target examination characteristics that did not lend themselves to traditional eye movement analysis methods. The development of this tool proved to be a valuable means of assessing visual activity at a micro level as compared to the gross measures of distribution of visual attention in various areas of the visual field.

This report describes the history surrounding the development of program cluster as an analysis tool, the source of input required for its execution, the mechanics of the execution as an interactive process, the program's products of visual displays and data file output, and potential application of such a tool for analysis of visual activity.

PROGRAM "CLUSTER" - AN IDENTIFICATION OF FIXATION CLUSTER CHARACTERISTICS

INTRODUCTION

Conducting a program of research is not always a simple, straightforward adherence to an experimental protocol. In the process of statistically analyzing the data obtained from even a well-designed research study, unexpected aspects of human behavior and performance are often exposed. The following describes a computer program designed and written to handle just such a situation resulting from a research endeavor (Birkmire, Karsh, Barnette, Pillalamarri, & Breitenbach, 1991) of the U.S. Army Human Engineering Laboratory (HEL) to aid designers of military tracked vehicles at the U.S. Army Tank and Automotive Command (TACOM). Specifically, these designers were interested in determining what vehicle design features (e.g., gun barrels, turrets, etc.) were more or less critical to identifying a vehicle viewed through an electronic imaging device, such as a forward looking infrared (FLIR) sensor.

HEL's visual performance team developed a research program to ascertain if eye movement behavior could be useful in determining what vehicle features appeared to be critical to target discrimination. An experiment was designed that used a methodology developed and reported by Gerhart, Graziano, and Carter (1983), whereby a stored image of a vehicle silhouette could be combined with a background of digitally generated gaussian noise. The result is a quantifiable simulation of a nonspecific sensor system image. The subjects' task was to visually examine a series of these images to identify one of eight different targets embedded in varying levels of target signal-to-background noise ratios (SNR).

Eye movement records were recorded at the rate of 60 Hz while a subject was engaged in the visual task. The data were subsequently processed off line into sequential eye fixation records (Karsh & Breitenbach, 1983) characterized by fixation spatial location coordinates and time durations. Literal graphic representations of these records, called fixation scan paths, were scaled and superimposed over these respective source images. An examination of these composites showed that fixations tended to be grouped into a cluster near the target as expected. However, it was determined that the apparent location of fixation clusters were at sites some 1.7 to 3.0 visual degrees distant and in varying directions from the actual target sites, while the expected location of such clusters would have been within 1.0 visual degree of the target. These unexpected offset distances made it impossible for traditional mapping techniques to be used to specifically align fixation locations to actual target features.

Various hypotheses concerning possible machine- or task-induced errors were suggested to account for the source and magnitude of such offset distances (Birkmire, Karsh, Barnette, Pillalamarri, & Breitenbach, 1991). Hypotheses related to machine-induced errors include possibilities for poor system mirror and subject head alignments and/or calibrations, and possibly an introduction of noise into the data stream. Hypotheses related to task-induced errors were developed considering the type of the task (i.e., search as opposed to reading or casual picture viewing). The instrument used to collect the eye movements was carefully examined, and no mechanical problems were found. In a further test of the system, eye movement data were collected for several other tasks in addition to the target discrimination task. Subsequent examination of these data failed to show offset distances of the size and magnitude found in the original data set. Consequently, the

hypothesis of machine error as a major source of the offsets was rejected. The offsets appeared to be task related, and since traditional mapping techniques were not usable with these data, program "CLUSTER" was developed to analyze the dynamics of the fixation clusters, independent of their absolute locations in space.

OBJECTIVES

It became an objective of this research to study various aspects of the dynamics of the fixation clusters in an effort to discover any underlying relationship between a fixation cluster's spatial characteristics and its offset distance compared to the actual target characteristics. This objective gave rise to producing a computer program to identify and quantify cluster characteristics.

PROGRAM "CLUSTER"

An algorithm was developed to allow the user, given a scan path record from a target identification task, to isolate and code those fixations believed to be associated with the target examination part of the record, to characterize the nature of the spatial area that the resultant cluster occupied, and to measure the offset distance of the center of the cluster area from the center of the actual location of the target embedded in the noise field. Following is a full description of the development, mechanics, execution, and potential uses of the program.

Method

Materials

For input, program "CLUSTER" requires a file of fixation records that have already been reduced from the original data collected at the time the subject was performing the visual identification task. Each fixation file (one per subject) contains records representing the eye movement history for that subject's visual behavior during the presentation of 16 images or stimulus slides. Figure 1 represents data for the first of 16 slides. The initial four records in the fixation file contain summary information for those 16 slides. Information in these four records include a subject identification code, total number of slides for which eye movement records exist, and the number of fixations made for each of the 16 slides presented. Following the initial summary records are 16 segments of records (one segment per slide) containing three records of slide summary information and detailed records of fixation information for each fixation made while viewing the slide. Slide summary information includes the actual slide number, number of fixations for the slide, x and y coordinates of the actual target location, target location code, total exposure time, mean fixation duration time, mean spatial distance between fixations, target type, signal-to-noise ratio, target response code, and type of response code. Each fixation record includes the fixation number, x coordinate, y coordinate, fixation duration, and distance from the previous fixation.

1100	16	8	6	2
10	10	6	13	3
7	10	10	9	9
7	8	8		
60	8	16	101	22
303	0.573	63	5	12
3	1			
1	27	17	16	0
2	72	88	13	84
3	88	102	62	21
4	56	102	22	32
5	100	89	37	45
6	55	94	31	45
7	19	-3	9	103
8	77	96	85	114

Figure 1. Sample of fixation file record format (sample includes fixation information for Subject 10, Slide 1).

Apparatus

The unprocessed, frame-by-frame real-time data were collected and stored on a Digital Equipment Corporation (DEC®) PDP™ 11/84 minicomputer, interfaced to a TEKTRONIX® 4014 cathode ray tube (CRT) terminal, running under the RT-II™ operating system. Only the initial levels of processing to create subject fixation files were completed on this system. The fixation files were downloaded, via ASCII file transfer in a communications software package, to a Zenith Data Systems ZWX-248 microcomputer for subsequent levels of processing. This transfer was necessary to take advantage of graphics capabilities available on personal computers (PCs) that typically do not exist on larger systems with CRT terminals. The advent of PCs, with their increased availability of graphical techniques, makes the development of analysis methodologies like that of program cluster possible. The Zenith system is configured with the MS-DOS® operating system, dual internal floppy disk drives, 20-megabyte internal hard drive, red-green-blue (RGB) color monitor, and a Hewlett-Packard laserjet printer. Program "CLUSTER" was written with a Microsoft® GW-BASIC™ (version 3.2) software package.

Design

In general, a scan path record of a subject's eye movement history derived from a visual identification task, in which the target is visible but embedded in varying levels of gaussian noise, typically consists of three types of looking behavior. Some initial fixations relate to the eye moving toward the target site. There are some brief orienting fixations in which the

eye stabilizes at or near the target location, after which fixations accumulate or cluster at the target site where examining behavior for target identification takes place. A scan path depicting such eye movement behavior and the target area is shown in Figure 2. Figure 3 provides a zoomed view of the fixation cluster and target area. Lines are drawn between fixation vectors to preserve for the viewer the order of fixation occurrence. The allocation of which fixations go with the target examination phase of the task is not well defined and cannot be modeled as a deterministic process. Subjective judgments are made concerning factors of spatial and temporal relatedness of fixation coordinates comprising a cluster, as well as the proximity and direction of that cluster from the target site. Another dimension of the subjective judgment of relatedness of fixations within a cluster is fixation duration. Fixations associated with target search behavior have shorter durations (Scanlan & Agin, 1978) than fixations associated with the kind of examining behavior that creates clusters at target sites. While some criteria can be spelled out and possibly formulated with some difficulty as a set of rules determining the inclusion or exclusion of fixations that may be functionally related, subjective assessments take many factors into account that are not easily articulated nor easily formulated into deterministic rules. Deterministic rules require establishing thresholds of event characteristics that classify the event into one class or another. Many events, however, have characteristics whose thresholds fall on the decision boundaries. Formulating decisions that use fuzzy rules work best in environments with such phenomena, but the problem of determining the amount of fuzziness and the nature of it still has to be deterministically specified. Thus, a decision was made against developing an automated, deterministic process for classifying a fixation as included or excluded from the target identification cluster.

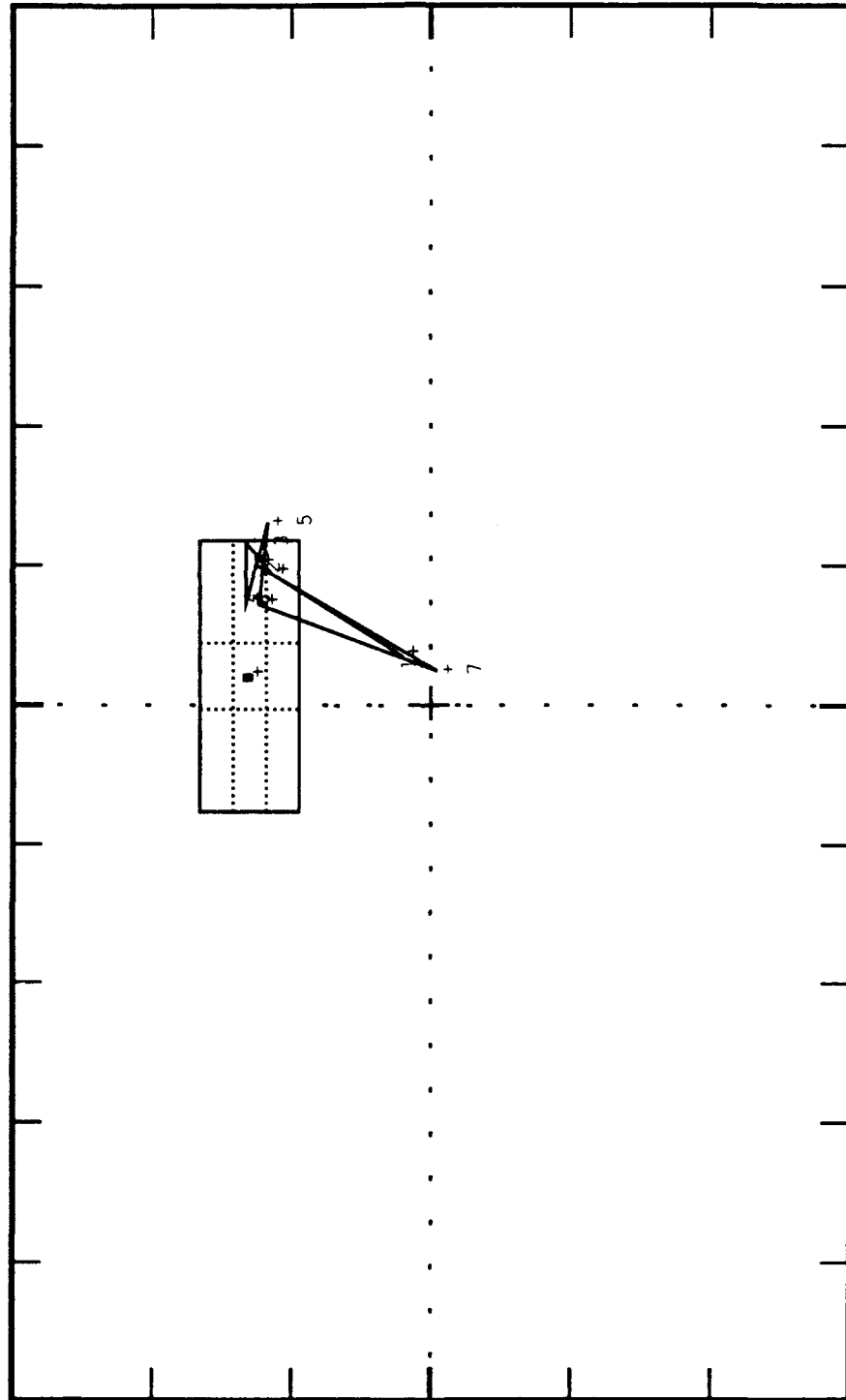
Program "CLUSTER's" user interface was written with the desire to establish a simple and easy-to-use approach to a complex problem. This had been accomplished with the user's ability to assign and/or change fixation classifications (i.e., included or excluded) at will and as many times as necessary until the user is satisfied that the appropriate fixations have been selected to comprise the cluster related to target examination. This feature is particularly important given that a subjective judgment about a fixation's classification may hinge on characteristics of the fixation(s) following, as well as preceding, the current point. Again, such a process would be extremely difficult if not impossible to include in a deterministic process. Once the target cluster has been defined, a number of parameters describing the cluster are calculated. Let us now take a closer look at the mechanics of program "CLUSTER."

Procedure

Following is a description of the execution of program "CLUSTER." The procedures for levels of user interaction and the functions of algorithms embedded in the program are described.

Upon execution, program "CLUSTER" first prompts the user to input the number of the subject to be processed. This number is embedded in the fixation data file name. Thus, a search is made within the current working directory for the fixation file for this subject. When the file has been located, it is opened, and the user is prompted to enter the number of slides to be skipped over. Some studies include slides between actual stimulus slides in which verbal responses are made, or perhaps the user is interested in looking only at slides meeting certain criteria. This option allows the user to skip over those slides to get to the ones of interest. When the records for the

OF FIXATIONS: 8 BOX LOCATION: (16 , 101) CELL SIZE: 36 STEP SIZE: 10
 FIXATION FILE: FIXNS.10 SLIDE: 1 / 0 TARGET CODE: 22 WINDOW SIZE: 300

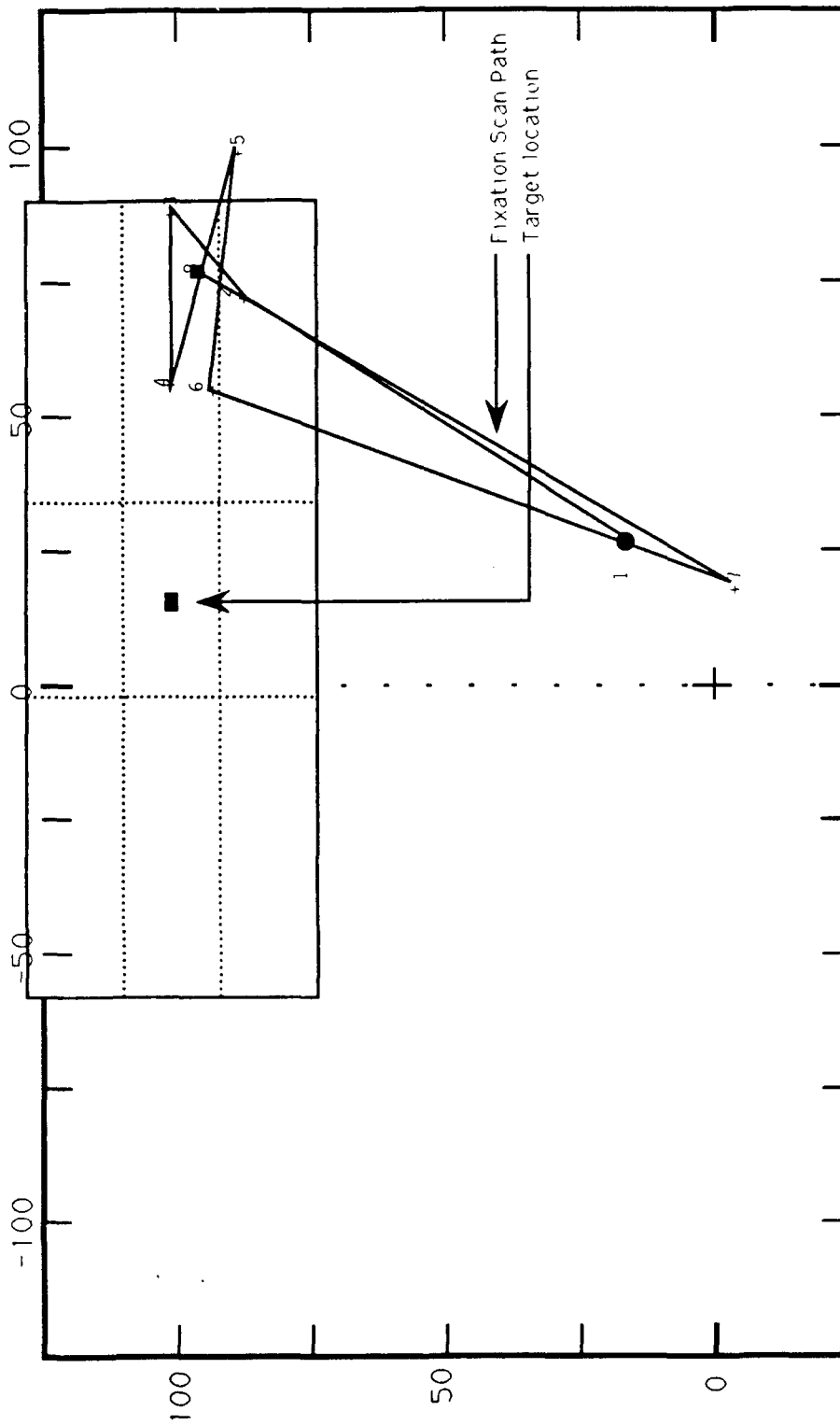


PRESS ANY KEY
 TO CONTINUE

#	Dur	Status
1	16	: EXCLUDED
2	13	: INCLUDED
3	62	: INCLUDED
4	44	: INCLUDED
5	37	: INCLUDED
6	31	: INCLUDED
7	9	: EXCLUDED
8	85	: INCLUDED

Figure 2. Fixation scan path for Subject 10, Slide 1.

OF FIXATIONS: 8 BOX LOCATION: (16 , 101) CELL SIZE: 36 STEP SIZE: 10
 FIXATION FILE: FIXNS.10 SLIDE: 1 / 0 TARGET CODE: 22 WINDOW SIZE: 300



PRESS ANY KEY
TO CONTINUE

#	Dur	Status
1	16	EXCLUDED
2	13	INCLUDED
3	62	INCLUDED
4	44	INCLUDED
5	37	INCLUDED
6	31	INCLUDED
7	9	EXCLUDED
8	85	INCLUDED

Figure 3. Fixation scan path for Subject 10, Slide 1 (zoomed to show detail).

first slide of interest have been located, the fixation data for that slide are read and subsequently displayed on the monitor. Figure 4 is a reproduction of what is shown on the user's monitor. Only the fixation x and y coordinates and the duration are displayed. The top and right side of Figure 4 shows several variables for which values do not yet exist. At this point, the user enters a carriage return to advance to the next stage of processing.

This next stage displays the subject's scan path for the current slide along with a nine-cell box displayed directly over the actual target area. The right side of the screen has the duration data for fixation number one displayed. The program is waiting for the user to make a decision about whether the fixation should be included in the target examination cluster. The current fixation of interest is highlighted in the scan path so that the user has a visual placement of the fixation in relation to other potential cluster fixations. The user enters a carriage return to include it or a space bar response to exclude it. After the user has responded in the same manner to all the fixations that follow, s/he is prompted to indicate whether s/he chooses to change the status of any of the fixations. The user may randomly pass through the fixation list as many times as necessary until s/he feels comfortable with the selection of fixations to create the target examination cluster. When this selection phase has been completed, the user enters a carriage return to proceed to the next level of processing. At this stage, the nine-cell target box is relocated from the actual target position and drawn directly over the center of the user-selected target examination cluster. The monitor display shown at this point is represented in Figure 5.

In addition to the nine-cell target box over the cluster, a rectangular box is drawn that strictly encompasses only the smallest possible area of the target examination cluster. Subsequently, a convex polygon is drawn around the outer points of the cluster. This polygon represents what one would see if a pin were stuck into each of the cluster points and a rubber band were placed around the bordering pins. Figure 6 provides a zoomed view of the cluster and target areas described in Figure 5.

The following is a discussion of the computer algorithms for calculating the distance, cell distribution, and convex polygon parameters. Distance parameters are calculated based on the distance between the center of the actual target position and the center of the target examination cluster. The center of the actual target position is calculated by defining a polygonal shape (or more basically a rectangle) that encompasses the outer boundaries of the vehicle silhouette, and by determining the center vector of that rectangle. The center of the target examination cluster, as defined by the fixation points associated with the target identification task, can be calculated by at least three different methods. The first of these methods is to calculate the mean fixation position (x,y) in which

$$(x,y) = (1/n) * [\sum(x_i), \sum(y_i)], \text{ in which } i \text{ ranges from } 1 \text{ to } n.$$

A second method is to calculate the weighted mean fixation position in which each fixation position is weighted by the fixation duration at that point (x,y) in which

$$(x,y) = (1/\sum(d_i)) * [\sum(x_i * d_i), \sum(y_i * d_i)], \text{ in which } i \text{ ranges from } 1 \text{ to } n.$$

OF FIXNS: 0 BOX LOCATION: (0 , 0) CELL SIZE: 36 STEP SIZE: 10
 FIXATION FILE: FIXNS.10 SLIDE: 1 / 0 TARGET CODE: WINDOW SIZE: ±

READING FIXATION FILE: FIXNS.10, SLIDE: 1

TO CONTINUE, PRESS ANY KEY

NUM	X-POS	Y-POS	DURATION
1	27	17	16
2	72	88	13
3	88	102	62
4	56	102	22
5	100	89	37
6	55	94	31
7	19	-3	9
8	77	96	85

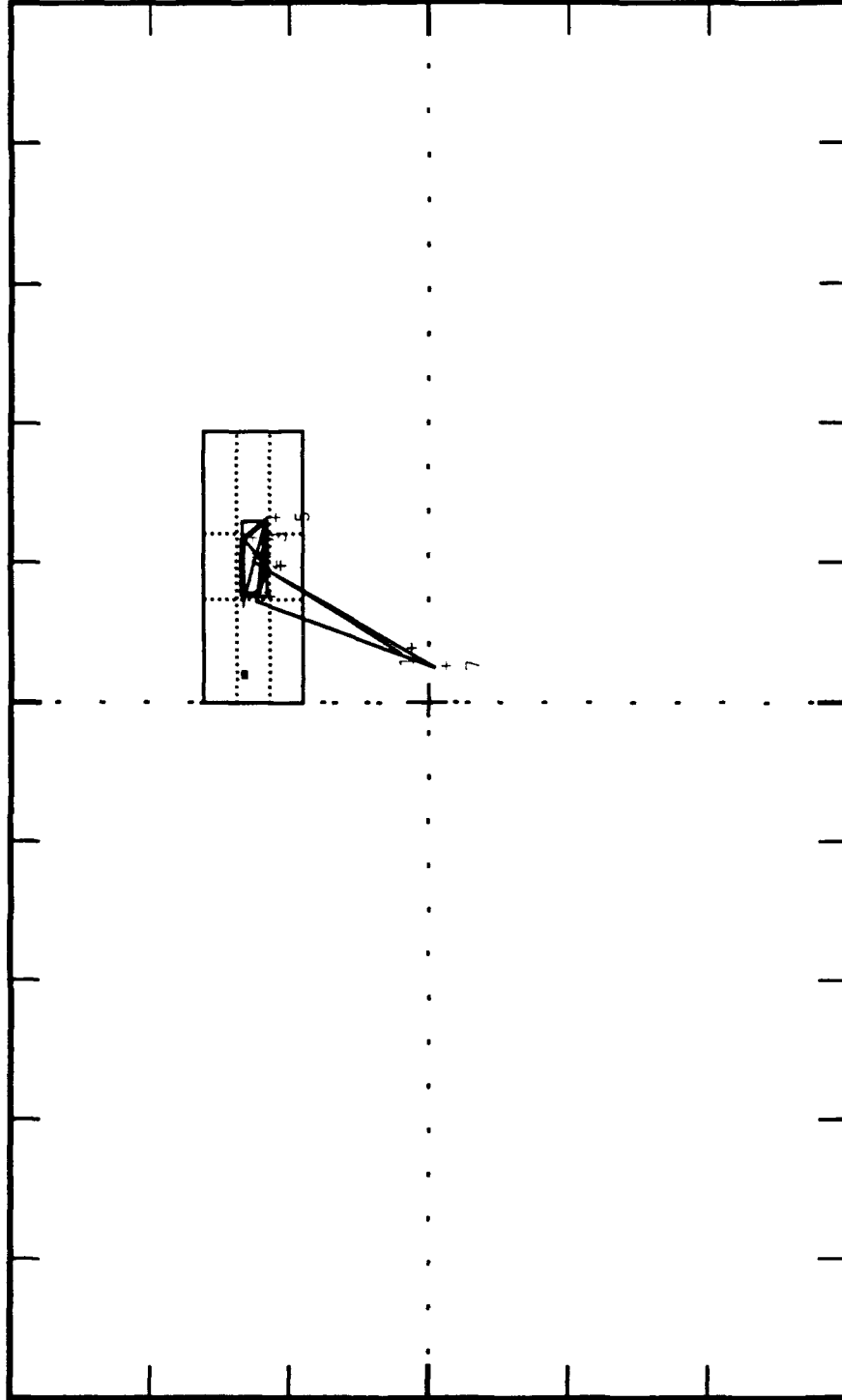
AREA:	NUM	NFX	NDR
AREA:	1		
AREA:	2		
AREA:	3		
AREA:	4		
AREA:	5		
AREA:	6		

TARGET OFFSET: (,)
 OFFSET DISTANCE:

FIXNS. INSIDE:
 TOTAL DURATION: TO
 X-RANGE: TO
 Y-RANGE: TO
 RANGE AREA:

Figure 4. Monitor display of fixation data for Subject 10, Slide 1.

OF FIXATIONS: 8 BOX LOCATION: (74 , 95) CELL SIZE: 36 STEP SIZE: 10
 FIXATION FILE: FIXNS.10 SLIDE: 1 / 68 TARGET CODE: 22 WINDOW SIZE: 300



Area:	NUM	NFX	NDR
Area: 1	0	0	0
Area: 2	0	0	0
Area: 3	0	0	0
Area: 4	1	1	31
Area: 5	4	4	182
Area: 6	1	1	37
Area: 7	0	0	0
Area: 8	0	0	0
Area: 9	0	0	0

Target Offset: (50, 6)
 Offset Distance: 50
 Fixations, Inside: 6
 Total Duration: 250
 X-Range: 55 to 100
 Y-Range: 88 to 102

Figure 5. Monitor display showing a nine-cell rectangle placed directly over the target examination cluster for Subject 19, Slide 1.

OF FIXATIONS: 8 BOX LOCATION: (74 , 95) CELL SIZE: 36 STEP SIZE: 10
 FIXATION FILE: FIXNS.10 SLIDE: 1 / 68 TARGET CODE: 22 WINDOW SIZE: 300

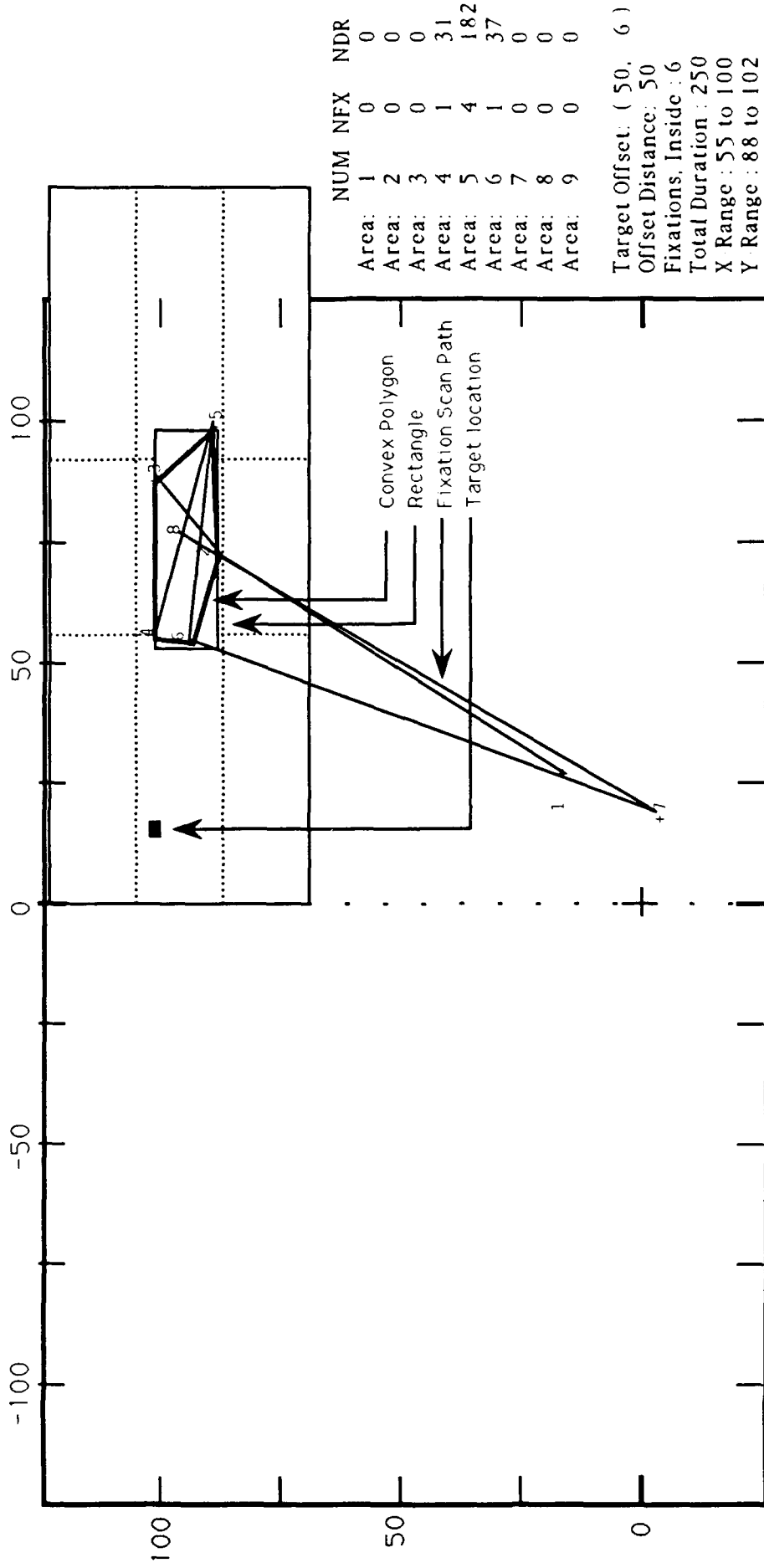


Figure 6. Monitor display showing a nine-cell rectangle placed directly over the target examination cluster for Subject 19, Slide 1 (zoomed to show detail).

Finally, a third method is to calculate the center of the convex polygon that encompasses the fixations of the target examination cluster. The center of the cluster is calculated as the weighted (by area) mean position (x,y) of the centers of the triangles that, when joined, form the convex polygon. The following calculations are made to compute that area:

Let (x_i, y_i) , in which $i=1,2,\dots,m$, be the coordinates of the convex polygon. The first of the $(m-2)$ triangles will be composed of points 1,2,3 of the convex polygon. The center of the area of this triangle is

$$(X_1, Y_1) = (1/3) * [x_1+x_2+x_3, y_1+y_2+y_3], \text{ and the area of the triangle is}$$

$$A_1 = 0.5 * | x_1*(y_2-y_3) + x_2*(y_3-y_1) + x_3*(y_1-y_2) |.$$

Thus, the area of the polygon is

$$A = A_1 + A_2 + \dots + A_{m-2}, \text{ and the center of the area of the polygon is}$$

$$(X, Y) = [\sum A_i * (X_i, Y_i)] / A, \text{ in which } i \text{ ranges from } 1 \text{ to } m-2.$$

It is noted here that the area of the convex polygon is always smaller than the area of the rectangle, except in the case when the polygon and the rectangle are identical. A discussion follows that describes an algorithm that determines an m -sided convex polygon, its area and center, for a given set of n points.

The offset distance from the center of the actual target position to both the weighted mean fixation position of the rectangular area and the center x,y position of the convex polygon are now calculated in the program.

The target area is divided into nine cells produced from three rows and three columns. The bordering cells of the matrix are expanded 0.5° to account for fixation over- and under-shoot to the feature visually examined. This nine-cell matrix is then overlaid onto the center of the target examination cluster, and a new monitor display is created to show this. Program "CLUSTER" then calculates the distribution of fixations and their durations of the target examination cluster into the nine cells. The frequency count of fixations and the sum of their durations for each cell are then calculated as both an absolute measure of visual attention to specific target areas as well as a proportion of the total visual looking time spent on the target.

The algorithm that defines the convex polygon takes the given set of arbitrarily ordered n points in a two-dimensional space that comprises the target examination cluster and finds an m -sided ($m \leq n$) convex polygon that includes all the points.

The set (p,q) is said to be convex if and only if any point r , in which

$$r = \beta * p + (1-\beta) * q, \text{ is a member of the set, for } 0 \leq \beta \leq 1.$$

Generalizing this, a convex polygon, can be mathematically defined as the geometrical area that always includes the (x,y) pair,

$$(x,y) = [\beta * x_i + (1-\beta) * x_j, \beta * y_i + (1-\beta) * y_j] \text{ in which}$$

(x_i, y_i) , (x_j, y_j) are two points in the fixation cluster, and β is a real number, $0 \leq \beta \leq 1$.

Again, the resulting geometrical shape resembles what would appear if pins were stuck in all the n points and a rubber band were placed around the entire set of n points. The following iterative algorithm determines such a convex polygonal shape.

1. Of the n points in the cluster, find the left-most point. Alternately, the algorithm can be modified to work with the right-most, top-most, or bottom-most point. In case there is a tie, any one of the competing points may be chosen. This point is the first vertex of the convex polygon.

2. With reference to a vertical line passing through this vertex, calculate the amount of angular shift, as the line tilts clockwise to meet the i_{th} point in the cluster. Let this angle be θ . Of all the $(n-1)$ such angles, the smallest angle is selected. If it belongs to the j_{th} point in the cluster, it is labeled the second vertex of the convex polygon.

3. The first and second vertices of the convex polygon are joined, extending the line beyond the points. Using the second vertex as the pivot, the angular shifts are calculated as the line is rotated clockwise to meet each of the other $(n-2)$ points. The cluster point associated with the smallest of the $(n-2)$ angles is labeled the third vertex of the convex polygon. This process is repeated until the vertex selected corresponds to the first vertex. At this point, the polygon is complete, and m -vertices, with $(m \leq n)$, will have been defined.

4. The resulting polygon of m -vertices is broken up into $(m-2)$ triangles. The area and center of each triangle are calculated. The center of the convex polygon is defined as the weighted mean center of all the triangles.

When program "CLUSTER" has performed all these calculations, a final summary of cluster parameters is written to both an offset data disk file and on the Hewlett-Packard laserjet printer. The summary contents include (a) horizontal and vertical range, center, and enclosed area (by a rectangular box) of the cluster; (b) mean fixation position of the cluster; (c) weighted mean fixation position of the cluster; (d) convex polygon enclosing the cluster fixations; (e) center and area of the convex polygon; (f) distance (offset) from the center of the polygon to the center of the actual target location; and (g) distribution of fixations in a nine-cell grid area covering the area of the target.

CONCLUSIONS

Although the development of program cluster may have been somewhat serendipitous, its value as a new tool to extract meaning from eye movement data has proved to be more than useful (Birkmire, Karsh, Barnette, Pillalamarri, & Breitenbach, 1991). Historically, emphasis on advancements in eye movement research have primarily been placed in the development of techniques and equipment to record eye movements (Young & Sheena, 1975). Further, the use of eye movement records to assess cognitive processing strategies have focused on fixation locations and time durations with respect to the placement of objects and text in the visual field. Program cluster, however, takes a step beyond that level of assessment of visual attention into the visual

behavior occurring during the examination stage of target identification. Specifically, given the nature of the data, with respect to the unexpected offset magnitude, traditional mapping techniques were not applicable. Program cluster provided a means to assess visual behavior in the absence of mapping target examination clusters to the absolute location of targets. While the employment of such an algorithm to parse and characterize target examination in a scan path seems a somewhat narrow application, the authors would make an appeal that such an approach could be informative with respect to the interpretation of any record of dynamic visual activity.

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APPENDIX A
SOURCE CODE LISTING FOR PROGRAM CLUSTER

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100 REM START TARGET OFFSET PROGRAM, RE-DEFINE FUNCTION KEYS, SET UP SCREEN
105 C$=CHR$(13):D$=CHR$(5) : KEY 4,"CLS"+D$+C$ : KEY 9, "COLOR 15,0"+D$+C$
110 KEY 7,D$ : KEY 10,"SAVE"+CHR$(34)+D$ : DEF SEG=0 : POKE &H417,192
115 KEY OFF :BS=36 :SS=10 :SCREEN 9 :COLOR 1,0 :WIDTH 80 :CLS
120 DIM X(50),Y(50),Z(50),T(50),FX(9),DR(9),NX(18)
125 REM
130 REM SET A WINDOW ON THE SCREEN AND DEFINE COORDINATES
135 VIEW (23,45)-(383,345),0,4 :CLS :WINDOW (-300,-300)-(300,300)
140 WIN=300 :GOSUB 315 ' PROMPT FOR SUBJECT NUMBER, READ FIXATION FILE
145 GOSUB 810 ' REDRAW THE PAGE, PRINT TITLES
150 GOSUB 245 ' FILLIN VALUES FOR PARAMETERS
155 Q$="415" :J=0 : ' PROMPT FOR CELL MOVEMENT
160 COLOR 15 :LOCATE 23,55 :PRINT "CHOOSE"; ' PROMPT C/S/D **
165 J=J+1 :J=J+3*(J=4) :R$=MID$("CELL SIZE STEP SIZE DIRECTION ",10*J-9,10)
170 POKE 1047,192-(J=3)*32 :COLOR VAL(MID$(Q$,J,1)):LOCATE 23,62 :PRINT R$:"";
175 X$=INPUT$(1) :IF ASC(X$)=32 THEN GOTO 165 ELSE Q$=X$ :PRINT X$;:COLOR 14
180 IF ASC(X$)<>13 THEN 195 ELSE LOCATE 23,55 :PRINT "TO END THIS SLIDE";
185 LOCATE 24,55 :PRINT "PRESS RETURN AGAIN"; 'LOCATE 24,55 :PRINT SPC(24);
190 X=ASC(INPUT$(1)) :GOSUB 685 :GOTO 225
195 IF J=3 THEN GOSUB 1025 :GOTO 155 ' *****
200 X$=INPUT$(1) :IF ASC(X$)=13 THEN 205 ELSE Q$=Q$+X$ :PRINT X$; :GOTO 200
205 IF K=1 THEN 225 ELSE Q=VAL(Q$) :IF Q=0 THEN 225 ELSE IF J=1 THEN GOTO 215
210 SS=Q :LOCATE 2,77 :COLOR 14 :PRINT SS; :COLOR 1 :GOTO 220
215 J=0 :GOSUB 985 :BS=Q :GOSUB 250
220 LOCATE 23,50 :PRINT SPC(29); :GOTO 155
225 COLOR 5 :LOCATE 23,55 :PRINT "FOR NEXT SLIDE, RETURN"; :LOCATE 24,55
230 PRINT"ANY KEY TO QUIT "; :X=ASC(INPUT$(1)) :IF X=13 THEN GOTO 240
235 COLOR 1,0 :CLOSE :VIEW :CLS :END ' *****
240 GOSUB 880 :GOSUB 425 :GOSUB 350 : GOTO 145 ' READ NEXT SLIDE & GO ON...
245 REM FILL IN ALL VARIABLE DATA ON THE FIRST TWO LINES, DRAW SCAN PATH ' **
250 COLOR 14 :LOCATE 2,14 :PRINT NFX;
255 LOCATE ,38 :PRINT AX;
260 LOCATE ,44 :PRINT AY; :LOCATE ,62 :PRINT BS; :LOCATE ,77 :PRINT SS;
265 LOCATE 3,74 :PRINT WIN; :LOCATE ,56 :PRINT TLC;
270 LOCATE 4,24 :PRINT GX; :LOCATE 14,3 :PRINT GY; :GOSUB 1065
275 COLOR 1 :CIRCLE (X(1),Y(1)),Z(1),1 :LINE (-300,-300)-(300,300),1,B
280 LINE (X(1)-3,Y(1)-3)-STEP(6,6),1,B :LINE (X(1),Y(1))-(X(2),Y(2)),1
285 FOR I=2 TO NFX:LINE -(X(I),Y(I)),1:C=1-14*(T(I)=0):CIRCLE (X(I),Y(I)),5,C
290 NEXT I :COLOR 14 :LOCATE 21,63 :PRINT LSX; :LOCATE ,71 :PRINT MSX;
295 LOCATE 22,63 :PRINT LSY; :LOCATE ,71 :PRINT MSY; :LOCATE 23,66
300 PRINT AREA; :LINE (LSX,LSY)-(MSX,MSY),15,B
305 COLOR 15 :LINE (TX-5,TY-5)-STEP (10,10),15,BF :GOSUB 980 :RETURN
310 REM
315 REM PROMPT FOR SUBJECT NUMBER, READ THE CORRESPONDING FIXATION FILE
320 COLOR 4:LOCATE 5,5:PRINT "ENTER SUBJECT NUMBER:--";:COLOR 1 'OPEN FILE
325 F$="FIXNS." :X$=INPUT$(1) :LOCATE ,26 :PRINT X$; :Y$=INPUT$(1) :PRINT Y$;
330 F$=F$+X$+Y$ :OPEN "I", #1, F$ :LINE INPUT #1, A$ :NX(1)=VAL(MID$(A$,11,5))
335 NX(2)=VAL(MID$(A$,16,5)) :NX(3)=VAL(MID$(A$,21,5)) :I=3 :MSL=3
340 FOR J=1 TO 3:LINE INPUT #1, A$:FOR K=1 TO 5:I=I+1:NFX=VAL(MID$(A$,5*K-4,5))
345 NX(I)=NFX :MSL=MSL-(NFX>0) :NEXT K, J :RA=0 :GOSUB 880 :GOSUB 425 ' *****
350 NSL=NSL+1 :IF NX(NSL)>0 THEN GOTO 365 ELSE CLS :LOCATE 10,5 :COLOR 14
355 PRINT "END-OF-DATA" :BEEP :GOTO 235
360 REM
365 CLS :LOCATE 5,5 :PRINT "READING FIXATION FILE: ";F$; ", SLIDE:";NSL
370 LOCATE 7,10 :PRINT "NUM X-POS Y-POS DURATION";

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375 K=4 :L=24 :GOSUB 630 :LSX=0 :MSX=0 :LSY=0 :MSY=0 :GOSUB 810
380 INPUT #1, ASL,NFX,AX,AY,TLC :INPUT #1, TTM,MDR,MDS,TTP,SNR
385 INPUT #1, TPR, RSP : FOR I=1 TO NFX :INPUT #1, J,X(I), Y(I), Z(I), K
390 T(I)=1 :K=J :IF K>16 THEN K=16
395 LOCATE 7+K,10 :PRINT I; :LOCATE ,20 :PRINT X(I); :LOCATE ,30 :PRINT Y(I);
400 LOCATE ,40 :PRINT Z(I); :NEXT I :TX=AX :TY=AY
405 COLOR 4 :LOCATE 6,10 :PRINT "TO CONTINUE, PRESS ANY KEY"; :X$=INPUT$(1)
410 CLS :GOSUB 515 :WINDOW (-300,-300)-(300,300) :WIN=300 :CLS
415 LINE (-300,-300)-(300,300),3,B :LINE (TX-5,TY-5)-STEP (10,10),15,BF
420 GOSUB 980 :RETURN
425 K=21 :L=22 :GOSUB 630 :IF NSL=MSL THEN GOTO 235
430 COLOR 10 :LOCATE 23,55 :PRINT "ENTER NUMBER OF SLIDES"; :LOCATE 24,55
435 PRINT"TO BE SKIPPED: ";:X$=INPUT$(1):IF X$="0" THEN 235 ELSE
X=VAL("&H"+X$)
440 IF NSL+X<MSL THEN GOTO 445 ELSE BEEP :LOCATE 22,55 :PRINT SPC(24);:GOTO
430
445 K=21 :L=22 :GOSUB 630
450 IF X=0 THEN RETURN ELSE FOR I=1 TO X :NSL=NSL+1 :LOCATE 21,55
455 PRINT "SKIPPING SLIDE:";NSL; :INPUT #1, ASL,NFX,AX,AY,TLC
460 LINE INPUT #1, A$ : LINE INPUT #1, A$ :FOR J=1 TO NFX :LINE INPUT #1, A$
465 NEXT J : NEXT I :LOCATE 20,55 :PRINT SPC(16); :RETURN
470 REM
ZOOM
475 CLS :LOCATE 20,52 :PRINT "ZOOMING...."; :LOCATE 21,52 : ' RE-DEFINE WINDOW
480 INPUT "ENTER WINDOW SIZE:",WIN :K=20 :L=21 :GOSUB 630
485 AX1=AX-WIN :AX2=AX+WIN : AY1=AY-WIN :AY2=AY+WIN
490 WINDOW (AX1,AY1)-(AX2,AY2) :LINE (AX1,AY1)-(AX2,AY2),3,B :FX=AX :FY=AY
495 LINE (AX1,AY)-STEP(2*WIN,0),15:LINE (AX,AY1)-STEP(0,2*WIN),15:LOCATE 4,24
500 LOCATE 3,70:PRINT WIN;:LOCATE 4,24:PRINT FX;:LOCATE 14,3:PRINT FY;:RETURN
505 CLS :VIEW (23,45)-(383,345),0,4 :CLS:WINDOW (-300,-300)-(300,300) :RETURN
510 REM
515 REM OPTIONAL SELECTION OF FIXATIONS
520 K=5 :L=24 :GOTO 570
525 COLOR 4 :MNX=X(1) :MXX=X(1) :MNY=Y(1) :MXY=Y(1) :FOR I=2 TO NFX
530 XX=X(I) :IF XX<MNX THEN MNX=XX ELSE IF XX>MXX THEN MXX=XX
535 YY=Y(I) :IF YY<MNY THEN MNY=YY ELSE IF YY>MXY THEN MXY=YY
540 NEXT I :I=200 :MNX=I*(MNX\I) :MNY=I*(1+MNY\I) :IF MNY<MNX THEN MNX=MNY
545 MXX=I*(1+MXX\I) :MXY=I*(1+MXY\I) :IF MXY>MXX THEN MXX=MXY
550 IF TX<MNX THEN MNX=TX ELSE IF TX>MXX THEN MXX=TX
555 IF TY<MNY THEN MNY=TY ELSE IF TY>MXY THEN MXY=TY
560 MNX=I*(MNX\I) : MXX=I*(1+MXX\I)
565 WINDOW (MNX,MNX)-(MXX,MXX) :WIN=(MXX-MNX)\2
570 GOSUB 245 :GOSUB 630 :COLOR 1 :LOCATE 4,55 :PRINT"SELECT FIXATIONS";
575 LOCATE 5,55 :PRINT "No. Dur Inc/Exc"; :COLOR 15 :FOR I=1 TO NFX
580 T(I)=0 :COLOR 15 :LOCATE 5+I,55 :PRINT I;Z(I); :COLOR 4 :LOCATE ,64
585 XX=X(I) :YY=Y(I) :LINE (XX-2,YY)-STEP(4,0),15 :LINE (XX,YY-2)-STEP(0,4),15
590 IF ABS(XX)>300 OR ABS(YY)>300 THEN FOR K=15 TO 25:SOUND 100*K,.1:NEXT K
595 X=ASC(INPUT$(1)) :PRINT ":INCLUDED"; :CL=-10*(X=13)
600 LINE (XX-2,YY)-STEP(4,0),CL :LINE (XX,YY-2)-STEP(0,4),CL
605 IF X=13 THEN GOTO 615
610 COLOR 1 :LOCATE ,64 :PRINT ":EXCLUDED"; : COLOR 15 :GOTO 615
615 T(I)--(X=13):NEXT I :GOSUB 640 :GOSUB 960 :K=4 :L=5 :GOSUB 630
620 GOSUB 760 :LOCATE 4,57 :COLOR 14 :PRINT "PRESS ANY KEY";
625 LOCATE 5,58 :PRINT "TO CONTINUE"; :X$=INPUT$(1) :K=4 :L=24
630 FOR J=K TO L :LOCATE J,51 :PRINT SPC(29); :NEXT J :RETURN
635 REM
640 COLOR 14 :REM CHECK FIXATION INCLUSION/EXCLUSION, MODIFICATION
645 J=5+I :LOCATE 4,55 :PRINT "TO CHANGE, PRESS ANY KEY"; :LOCATE 5,55
650 PRINT "ELSE, PRESS RETURN"; :LOCATE J,55 :PRINT SPC(20); :X$=INPUT$(1)

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655 COLOR 4:IF ASC(X$)=13 THEN RETURN ELSE K=4 :L=5:GOSUB 630
660 COLOR 14 :LOCATE 4,55 :INPUT "ENTER FIXATION #",K :IF K=0 THEN RETURN
665 REM OUTPUT DATA TO PRINTER
670 L=1-T(K) :T(K)=L :CL=1+14*L :COLOR CL :LOCATE 5+K,65
675 PRINT MID$("EXIN",2*L+1,2);"CLUDED"; :LINE (X(K)-2,Y(K))-STEP(4,0),CL
680 LINE (X(K),Y(K)-2)-STEP(0,4),CL :COLOR 15 :GOTO 645
685 RETURN :REM OUTPUT DATA TO THE PRINTER
690 X$=MID$("ABRMBRADTSTBCONCVULCHUMVFORKCARR",4*TTP-3,4) :LPRINT : REM PRINT
695 LPRINT "FIXATION FILE:";F$ :LPRINT "Actual Slide:";NSL;"/";ASL;" Number";
700 LPRINT " of Fixations:";NFX; :LPRINT " Target Location: (";TX;",";TY;)"
705 LPRINT "Target Type:";X$;" S/N=";SNR;" Response " :X$=" DET RECIDEN"
710 LPRINT "Category:";MID$(X$,4*TPR-3,4) :LPRINT "Time of Exposure:";
715 LPRINT TTM;"(Flds) Mean Duration:";MDR;"(Secs.) Mean Distance:";
720 LPRINT MDS :LPRINT "Offset: (";OX;",";OY;)" Offset Distance:";OXY%
725 LPRINT " Area No. Fixns Duration" :FOR J=1 TO 6 :LPRINT TAB(5);
730 LPRINT J;TAB(15);FX(J);TAB(25);DR(J) :NEXT J :LPRINT " Total:";
735 LPRINT TAB(15);IFX;TAB(25);IDR :LPRINT "For the Included Fixns, X-";
740 LPRINT "Range: (";LSX;" to ";MSX;)" :LPRINT TAB(26);"Y-Range: (";LSY;
745 LPRINT " to ";MSY;)"", "Area:";AREA :LPRINT "Included Fixations:";
750 FOR I=1 TO NFX:LPRINT T(I); :NEXT I:LPRINT :RETURN
755 REM
760 REM CALCULATE THE RANGE OF INCLUDED FIXATIONS
765 LSX=1000 :MSX=-1000 :LSY=1000 :MSY=-1000
770 FOR I=1 TO NFX :IF T(I)=0 THEN GOTO 795
775 JX=X(I) :IF LSX>JX THEN LSX=JX
780 IF MSX<JX THEN MSX=JX
785 JY=Y(I) :IF LSY>JY THEN LSY=JY
790 IF MSY<JY THEN MSY=JY
795 NEXT I :AREA=ABS((MSX-LSX)*(MSY-LSY)) :RETURN
800 FOR J=K TO L :LOCATE J,55 :PRINT SPC(24); :NEXT J
805 REM ***** START, SET-UP TITLES, AND PAGE FORMAT
810 COLOR 4 :LOCATE 2,3
815 PRINT "# OF FIXNS:";NFX;:LOCATE ,24:PRINT "BOX LOCATION:(";AX;:LOCATE ,43
820 PRINT ",";AY; :LOCATE ,49 :PRINT ") CELL SIZE:";BS; :LOCATE ,67
825 PRINT "STEP SIZE:";SS; :LOCATE 3,3 :PRINT "FIXATION FILE:"; :LOCATE ,29
830 PRINT "SLIDE:"; :LOCATE ,44 :PRINT "TARGET CODE:";
835 LOCATE ,60 :PRINT "WINDOW SIZE: ";CHR$(241);
840 LOCATE 6,62 :PRINT "NUM NFX NDR"; :FOR IB=1 TO 9 :LOCATE 6+IB,55
845 PRINT "AREA: ";IB; :NEXT IB :LOCATE 17,52 :PRINT "TARGET OFFSET: ( ";
850 PRINT " , )"; :LOCATE 18,52 :PRINT "OFFSET DISTANCE:"; :LOCATE 19,55
855 PRINT "FIXNS. INSIDE:"; :LOCATE 20,55 :PRINT "TOTAL DURATION:";
860 LOCATE 21,55 :PRINT "X-RANGE: TO"; :LOCATE 22,55 :PRINT "Y-RANGE: ";
865 PRINT " TO"; :LOCATE 23,55 :PRINT "RANGE AREA:"; :COLOR 14 :LOCATE 3,18
870 PRINT F$; :LOCATE ,35 :PRINT NSL; :LOCATE ,38:PRINT "/";ASL;:RETURN
875 REM
880 BEEP :REM STORE INFORMATION IN RANDOM ACCESS FILE
885 IF RA=1 THEN GOTO 895 ELSE OPEN "R", #2, "OFFSET"+RIGHT$(F$,3), 32
890 FIELD #2, 32 AS Z$ :RA=1 :BLNK$=STRING$(30,32)+CHR$(10)+CHR$(13) :RETURN
895 X$=BLNK$ :MID$(X$,1,2)=RIGHT$(F$,2) :MID$(X$,3,3)=STR$(TLC)
900 MID$(X$,6,2)=STR$(TTP) :MID$(X$,8,5)=RIGHT$(STR$(SNR),2)+STR$(ASL)
905 MID$(X$,13,3)=STR$(NFX) :MID$(X$,16,4)=STR$(TTM) :MID$(X$,20,5)=STR$(MDR)
910 MID$(X$,25,4)=STR$(MDS) :MID$(X$,29,2)=CHR$(TPR+48)+CHR$(RSP+48)
915 RSET Z$=X$ :I=4*NSL-3 :PUT #2, I :X$=BLNK$
920 MID$(X$,1,4)=STR$(OFX) :MID$(X$,5,4)=STR$(OFY) :MID$(X$,9,4)=STR$(OXY%)
925 MID$(X$,14,4)=STR$(LSX) :MID$(X$,18,4)=STR$(LSY)
930 MID$(X$,23,4)=STR$(ABS(MSX-LSX)) :MID$(X$,27,4)=STR$(ABS(MSY-LSY))
935 RSET Z$=X$ :PUT #2, I+1 :X$=BLNK$ :J=-4 :FOR K=1 TO 6
940 J=J+5 :MID$(X$,J,5)=RIGHT$(STR$(FX(K)),2)+RIGHT$(STR$(DR(K)),3) :NEXT K

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945 RSET Z$=X$ :PUT #2, I+2 :X$=BLNK$ :FOR J=1 TO NFX
950 K=T(J) :MID$(X$,J,1)=CHR$(48+K) :NEXT J :RSET Z$=X$ :PUT #2, I+3 :RETURN
955 REM CALCULATE MEAN FIXATION COORDINATES
960 J=0 :AX=0 : AY=0 : FOR I=1 TO NFX :IF T(I)=0 THEN GOTO 970
965 AX=AX+X(I) :AY=AY+Y(I) :J=J+1
970 NEXT I :FACT=1!/J :AX=INT(AX*FACT):AY=INT(AY*FACT):RETURN ' CALC FIXN MEAN
975 REM DRAW 9-CELL BOX AROUND TARGET/MEAN FIXATION POSITION
980 BA=.5*BS :BC=1.5*BS : BD=2*BS : BE=3*BS :J=1
985 LINE (AX-70,AY-36)-STEP(140,72),15,B,&HF0F0
990 LINE (AX-70,AY-12)-STEP(140,24),15,B,&HF0F
995 LINE (AX-18,AY-36)-STEP( 36,72),15,B,&HF0F
1000 RETURN
1005 REM
1010 REM MONITOR FOR DIRECTIONAL MOVEMENT OF BOX OR ZOOM
1015 X$=INPUT$(1) :COLOR 5 :LOCATE 23,73 :PRINT X$; :IF X$<>"Z" GOTO 1025
1020 POKE 1047,192 :GOSUB 475 :GOSUB 250 :POKE 1047,224 :GOTO 1015
1025 X=ASC(X$)-48 :IF X>0 AND X<10 THEN GOTO 1030 ELSE BEEP :GOTO 1015
1030 IF X=5 THEN GOTO 1055 ELSE DX=((X-1) MOD 3)-1 :DY=((X-1)\3)-1 :LOCATE 24,63
1035 D$=MID$("SOUTH NORTH",5*DY+6,5)+MID$(" WEST EAST",5*DX+6,5)
1040 PRINT D$; :J=0 :GOSUB 985 :AX=AX+DX*SS :AY=AY+DY*SS
1045 IF AX<-300+BC OR AX>300-BC OR AY<-300+BA OR AY>300-BA THEN BEEP
1050 GOSUB 250 :GOTO 1015
1055 LOCATE 23,60 :PRINT SPC(18); :LOCATE 24,63 :PRINT SPC(10); :RETURN ' *****
1060 REM
1065 FOR IB=1 TO 9 :FX(IB)=0 : DR(IB)=0 :NEXT IB ' CALCULATE CELL OCCUPANCIES
1070 IFX=0 :IDR=0 :FOR IP=M TO NFX :IF T(IP)=0 THEN GOTO 1105
1075 CX=X(IP) : CY=Y(IP) :EX=AX-70 :EY=AY-36
1080 IF CX<EX THEN 1105 ELSE BX=1 :EX=EX+52:IF CX<EX THEN 1090 ELSE BX=2:EX=EX+36
1085 IF CX<EX THEN 1090 ELSE BX=3 :EX=EX+52:IF CX<EX THEN 1090 ELSE GOTO 1105
1090 IF CY<EY THEN 1105 ELSE BY=1 :EY=EY+24:IF CY<EY THEN 1100 ELSE BY=2:EY=EY+24
1095 IF CY<EY THEN 1100 ELSE BY=3 :EY=EY+24 :IF CY<EY THEN 1100 ELSE GOTO 1105
1100 IB=3*(BY-1)+BX:FX(IB)=FX(IB)+1:IFX=IFX+1:DR(IB)=DR(IB)+Z(IP):IDR=IDR+Z(IP)
1105 NEXT IP :COLOR 14 :FOR IB=1 TO 9 :LOCATE 6+IB,67 :PRINT FX(IB);" ";
1110 LOCATE ,72 :PRINT DR(IB);" "; :NEXT IB
1115 LOCATE 19,70 :PRINT IFX; :LOCATE 20,70 :PRINT IDR;
1120 OX=AX-TX :OY=AY-TY :OXY%=SQR(OX^2+OY^2) :LOCATE 17,68
1125 PRINT OX; :LOCATE ,74 :PRINT OY; :LOCATE 18,70 :PRINT OXY%;: RETURN

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