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CONTROLLER VISUAL SCANNING BEHAVIOR MANUAL DATA COLLECTION AND ANALYSIS REPORT

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CONTROLLER VISUAL SCANNING BEHAVIOR

INTRODUCTION

On July 12, 1989, an on-line, active controller from the Atlantic City Tower volunteered to participate in our experiment on visual scanning behavior which consisted of collecting and analyzing eye movement activity of the controller seated before a radar display which exhibited simulated aircraft approaches on an ILS course. Subsequently, a video tape of the scanning behavior was given to a summer student employee (R.Messick) for reduction and analysis. The data was reduced and analyzed by the MANUAL DATA COLLECTION AND ANALYSIS METHOD; i.e., the data was recorded as scene-views generated by the ASL occulometer using the NTSC visual frames on a video cassette recorder (VCR). The data was collected-on and analyzed-from a Sony Beta-format VCR utilizing the helmet-mounted ASL scene-view camera as the primary sensor for the frame-by-frame analysis. A second identical radar display was utilized with a second higher resolution video camera to record the traffic sample in order to positively identify aircraft targets through usage of enlarged associative-data blocks. This second radar display-and-record set-up was completely independent and totally unrelated to the ASL occulometer system.

A frame is equivalent to 0.033 seconds and the total number of frames analyzed were 12,600 or, equivalently, 7 minutes of real-time data. For the purposes of this report, a fixation is defined as 5 frames or, equivalently, 0.16 seconds. This figure is consistent with established vision research statistics which conclude that fixation occurs over a range of 100 to 300 milliseconds. (Note: 100 milliseconds = 0.10 seconds & 300 milliseconds = 0.30 seconds). The total number of fixations identified over the 7 minute block was 346.

BAR CHART OF MEAN FIXATION TIMES Figure 1

Figure 1 is presented in the form of a bar chart with the vertical axis representing the fixation time in seconds and the horizontal axis representing seven one-minute time blocks. The darkened bars represent the average fixation time in seconds for each one-minute block. As an example, for time block Number 1, the average fixation time is 1.72 seconds and for block Number 2 the average fixation time is 1.49.

This chart shows that as time increased the average fixation time decreased and as the mean fixation time decreased the variance decreased proportionately. Two reasons could account for this phenomena: (1) the controller gained more familiarity with the radar display (PVD) and the test set-up as time increased and (2) there were more targets in the later minutes of the data collection phase than in the earlier minutes; i.e., the controller workload increased towards the latter portion of data collection time.

MEAN FIXATION TIMES AND FREQUENCY OF FIXATIONS VERSUS TIME BLOCKS Figure 2

The left-side vertical axis for this graph is the average fixation times in seconds, and the right-side vertical axis is the frequency of fixations, for each of the 1-minute time blocks along the horizontal axis. The line with the dot-circled points represents the mean fixation time (left-side axis) for each one-minute block as in the previous figure and the line with the asterisk or star points represents the number of fixations (right-side axis) for each one-minute block. This figure indicates that as the fixation frequency increases or as the number of fixations increases the average fixation time decreases.

TABLE I

Table I is a tabulation of the aircraft ID's versus seven columns - one column for each of the 1 minute time intervals over a duration of 7 minutes. The columns show number of fixations per aircraft over the range of 7 minutes. This graph shows the breakdown of the 346 fixations according to each time blocks and for each of the aircraft ID's. As an example, Delta 698 has a total of 6 fixations (1.7%) during the seven minutes. Note that Delta 698 was on the display for 57.70 seconds which is relatively small time interval as compared to other target aircraft. Time block Number 1 had 33 fixations out of the possible 346 (9.5%) while time block Number 6 had 67 (19.4%) fixations out of the possible 346.

TABLE II

Table II tabulates percentages of the total number of fixations as a function of aircraft ID's and 60 second-blocks of time intervals. Each of the seven rows shows the percentage of fixations for each of the 1-minute intervals. This percentage is further broken-down on a per aircraft ID-basis. The percent of fixations per minute is the sum of each row. For example, Time Block 1 shows a total percentage of 9.5% = 1.7% + 3.2% + 0.3% + 2.0% + 0.6% + 0.3% + 0.9% + 0.6% (Note that rounding-errors exist). In other words, 33 fixations or 9.5% of the total number occurred in the first 60 second block of time.

Each aircraft column shows the percentage of fixation frequencies for each of the 7 one-minute time blocks. For example, Delta 674 was fixated upon 51 times or 14.7% of the possible 346 fixations over the 7 minute test period; i.e. 14.7% = 0.6 + 1.7 + 2.6 + 4.9 + 2.3 + 1.7 + 2.3 + 0.9 + 0.6. Note that Delta 674 was the most fixated-upon target. Also note that Delta 674 was on the screen longer than any other target.

TABLE III

Table 3 is a tabulation of each of the aircraft ID's indicating the start and stop times of each of their appearances on the display and the total time that each ID spent on the display.

CONCLUSIONS

Based on the cross-tabulation of fixation frequency and time blocks as a function of aircraft ID's, the controller did not invest equal numbers of fixations per aircraft; rather, she unconsciously budgeted her scanning time with the displayed target information based on her own mental priority scheme. Apparently, her scanning profile is based on her own mental decision-making process which probably has been developed over a long period of her career tenure.

DISADVANTAGES OF MANUAL DATA COLLECTION

1. All targets displayed on the ASL scene-view monitor were unintelligible. --> In order to correct for this deficiency, a second identical radar display was utilized with a second higher resolution video camera to record the traffic sample in order to positively identify aircraft targets through usage of the associative-data blocks. The data blocks on the second radar display were enlarged to the maximum character size in order to make them intelligible on the second VCR tape.

2. The periodic overlapping of data blocks frequently prevented correct identification of some of the aircraft targets.

3. Cross-hairs moved off the screen which frequently inhibited continuous data collection.

4. Two unavoidable IR bleed-through's hindered positive identification of aircraft ID's. The IR source co-located at the pupil camera emits light which 'bleeds-thru' the clear plastic visor and is recorded on the scene-view VCR tape as a 'bright spot'.

5. CUMULATIVE ERRORS OCCUR DUE TO CODER FATIGUE AND DUE TO THE ROUNDING OF NUMBERS BY THE CODER.

ADVANTAGES OF MANUAL DATA COLLECTION AND ANALYSIS

1. Manual data collection and analysis enables the generation of 'spatial' tracking behavior; i.e., the results account for both head motion as well as eye motion. Albeit a tedious approach, it is better than nothing.

2. The manual or frame-by-frame method of reducing and analyzing data is much more detailed and conceivably could be used to ascertain an accurate profile of the physical scanning behavior of 'experienced' controllers. These profiles could be used as a 'bench-marks' or points-of-reference for determining the scanning behavior of the 'experts'.

3. This report on manual data collection and analysis can serve as a catalyst or incentive for interested organizations to consider expanding the scanning behavior efforts; specifically, in the underwriting and procurement of more sophisticated equipment to perform the same tasks in a more automated manner.

ACKNOWLEDGEMENT

Project personnel express their thanks to Robert Messick, summer student at the Technical Center, for his patience and untiring efforts in manually reducing the 7 minutes of VCR data and for producing the tabulations of the controller scanning behavior. As mentioned previously in this report, 7 minutes-worth of real-time data frames required visual examination of 12,600 video freeze-frames.

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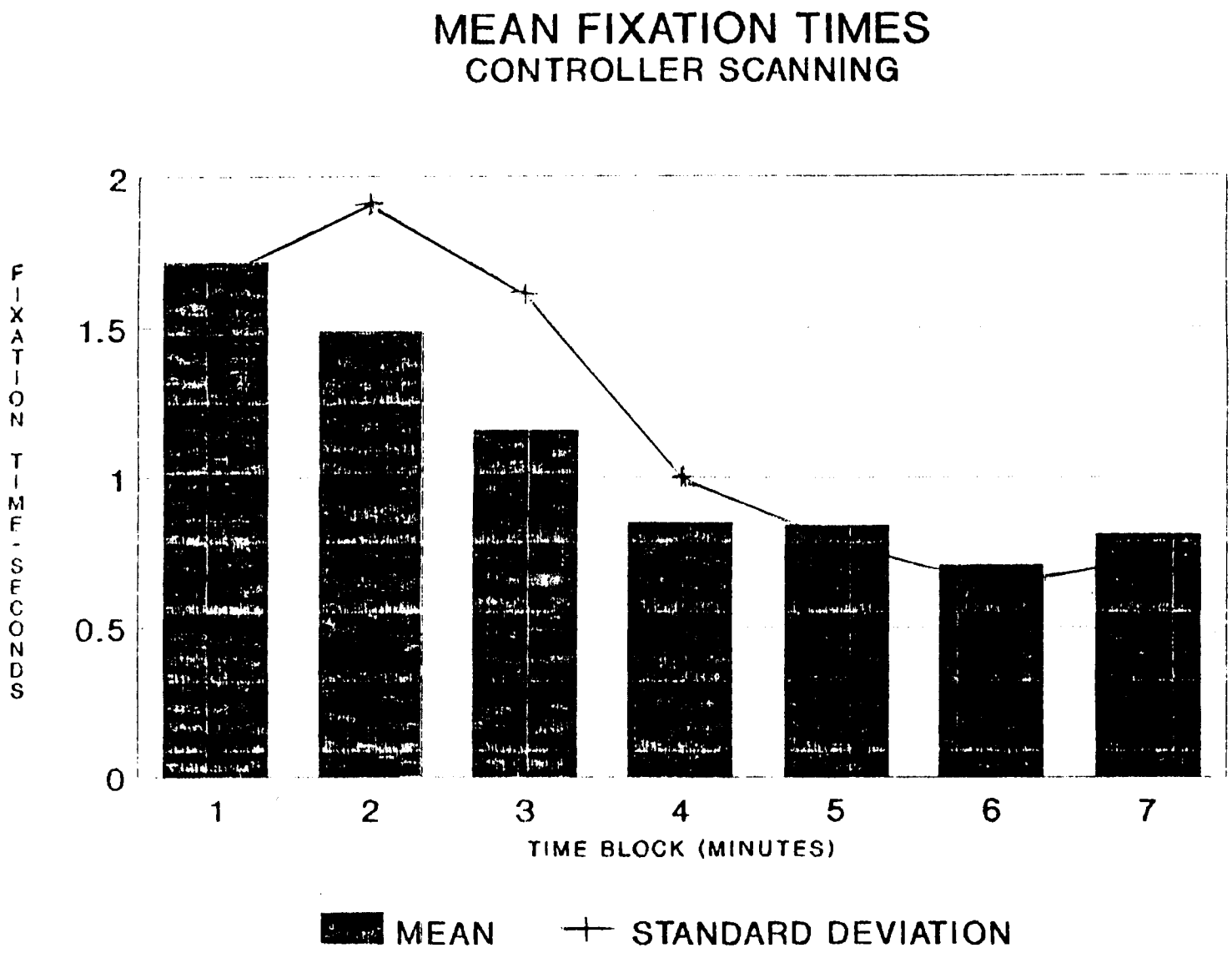
MEAN FIXATION TIMES
CONTROLLER SCANNING
FIXATION TIME - SECONDS
2
1.5
1
0.5
0
1
2
3
4
5
6
7
TIME BLOCK (MINUTES)
MEAN
STANDARD DEVIATION

FIGURE 1

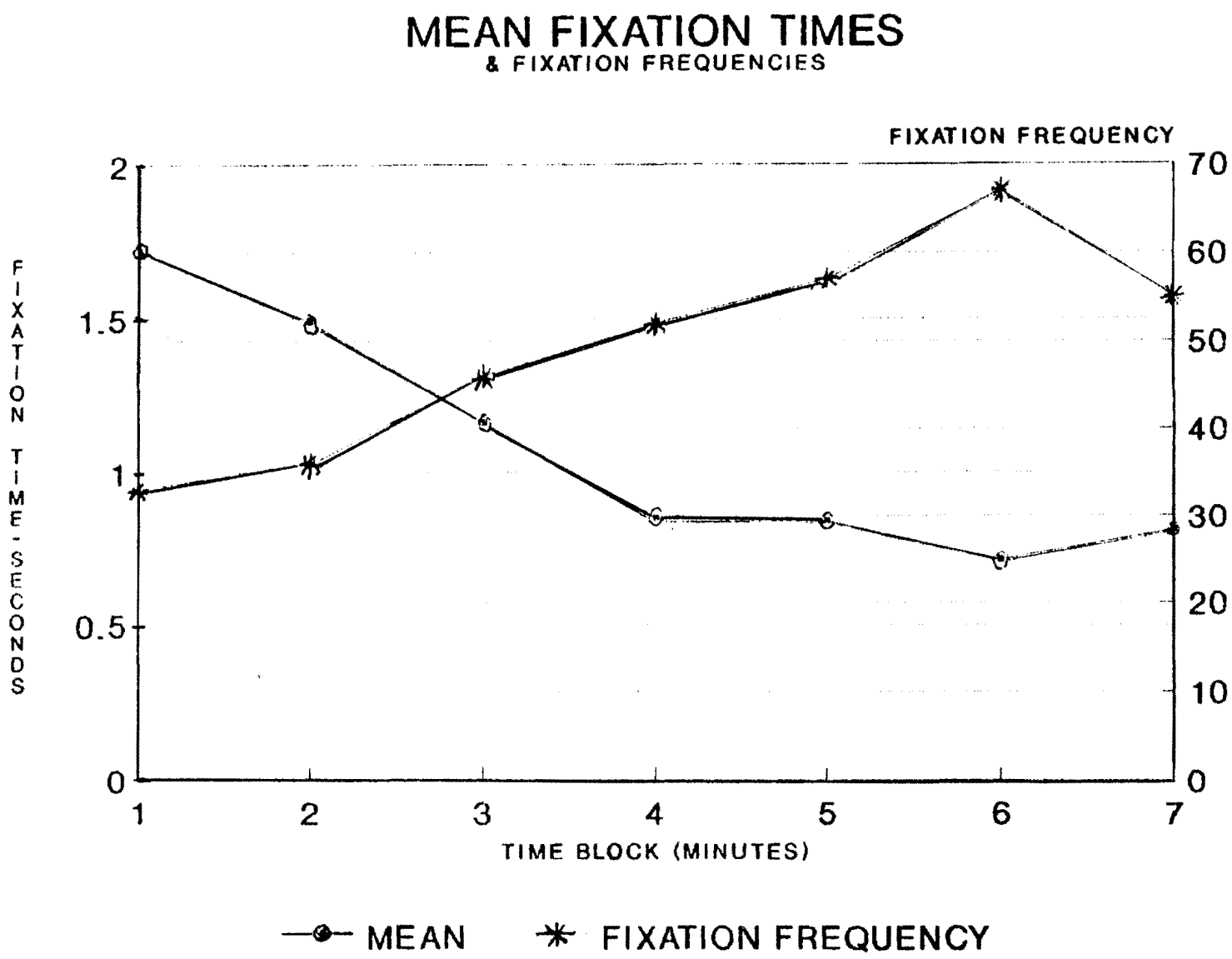
MEAN FIXATION TIMES
& FIXATION FREQUENCIES
FIXATION FREQUENCY
FIXATION TIME-SECONDS
2
1.5
1
0.5
0
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
TIME BLOCK (MINUTES)
MEAN
FIXATION FREQUENCY

FIGURE 2

TABLE I

Total # of Fixations = 346

Aircraft Identification	Time Block # of Fixations Total	1st Min. 33	2nd Min. 36	3rd Min. 46	4th Min. 52	5th Min. 57	6th Min. 67	7th Min. 55
Delta 698	6	6	0	0	0	0	0	0
Republic 302	11	11	0	0	0	0	0	0
Amer. Airlines 533	6	1	0	5	0	0	0	0
Amer. Airlines 537	43	7	11	13	8	4	0	0
Delta 674	51	2	6	9	17	6	8	3
Braniff 575	42	1	3	9	5	5	12	7
Amer. Airlines 39	30	0	2	4	5	2	7	10
N756N	28	0	0	0	6	6	10	6
Amer. Airlines 944	45	0	0	0	9	14	11	11
Amer. Airlines 101	28	0	0	0	1	11	7	9
Amer. Airlines 60	13	0	0	0	0	4	5	4
Delta 538	2	0	0	0	0	0	2	0
Track Ball Cursor	13	2	0	0	0	4	3	4
Unknown Data Tag	3	0	1	1	0	0	1	0
Rep. 302/AA 533	17	3	13	1	0	0	0	0
IR Bleed Thru	1	0	0	0	0	1	0	0
Right Data Block	7	0	0	4	1	0	1	1

TABLE II

Total Fixations = 346

	Aircraft Id Fixation Freq.	Delta 698 1.7	Rep.302 3.2	AA 533 1.7	AA 537 12.4	Delta 674 14.7	Bran. 575 12.1	AA 39 8.7	N756N 8.1	AA 944 13.0	Rep302/AA 533 4.9
Time Block	% of Fixations per minute										
1	9.5	1.7	3.2	.3	2.0	.6	.3	.0	.0	.0	0.9
2	10.4	.0	.0	.0	3.2	1.7	.9	.6	.0	.0	3.8
3	13.3	.0	.0	1.4	3.8	2.6	2.6	1.2	.0	.0	0.3
4	15.0	.0	.0	.0	2.3	4.9	1.4	1.4	1.7	2.6	.0
5	16.5	.0	.0	.0	1.2	1.7	1.4	.6	1.7	4.0	.0
6	19.4	.0	.0	.0	.0	2.3	3.5	2.0	2.9	3.2	.0
7	15.9	.0	.0	.0	.0	.9	2.0	2.9	1.7	3.2	.0

cont'd.

	Aircraft Id Fixation Freq.	AA 101 8.1	AA 60 3.8	Delta 538 0.6	Track Ball Cursor 3.8	Unk. Data tag 0.9	Data Block 2.0	IR Bleed Thru 0.3
Time Block	% of Fixations per minute							
1	same as above	.0	.0	.0	.6	.0	.0	.0
2	"	.0	.0	.0	.0	.3	.0	.0
3	"	.0	.0	.0	.0	.3	1.2	.0
4	"	0.3	.0	.0	.0	.0	.3	.0
5	"	3.2	1.2	.0	1.2	.0	.0	.3
6	"	2.0	1.4	0.6	0.9	.3	.3	.0
7	"	2.6	1.2	.0	1.2	.0	.3	.0

TOTAL AIRCRAFT TIME ON VIDEO DISPLAY SCREEN

Aircraft Identification	Entering Time	Leaving Time	Total Time
Delta 698	00:00.03	00:57.73	00:57.70
Republic 302	00:00.03	02:21.90	02:21.87
Amer. Airlines 533	00:00.03	02:41.77	02:41.74
Amer. Airlines 537	00:00.03	05:02.10	05:02.07
Delta 674	00:00.03	07:00.00	06:59.97
Braniff 575	00:03.00	07:00.00	06:57.00
Amer. Airlines 39	01:03.23	07:00.00	05:56.77
N756N	01:41.23	07:00.00	05:18.77
Amer. Airlines 944	02:03.37	07:00.00	04:56.63
Amer. Airlines 101	03:54.37	07:00.00	03:05.63
Amer. Airlines 60	04:22.67	07:00.00	02:37.33
Delta 538	05:40.73	07:00.00	01:19.27
Rep. 302/AA 533	00:00.03	02:21.90	02:21.87
Track Ball Cursor	N/A	N/A	N/A
Unknown Data Tag	N/A	N/A	N/A
IR Bleed Thru	N/A	N/A	N/A
Right Data Block	N/A	N/A	N/A

Note: Total time of run = 07:00.00

TABLE 3