Tethered insect flight: A computer program to analyze behavioral events

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Insect Attractants

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In entomological research, a flight mill is a piece of equipment used to analyze the flying ability of insects. The design and construction of an insect flight mill and the data-acquisition system that interfaces with the computer program presented herein are described by Chambers, Sharp, and Ashley (1976).

The purpose of this paper is to describe and illustrate the use of a computer program for analyzing behavioral data, in this instance, gathered from an insect flight-mill system consisting of 18 individual mills and an 18-channel event recorder that stores behavioral events on a seven-track computer tape. This computer program, written in FORTRAN IV, was planned so that individuals with little or no experience in computer techniques would be able to utilize it as part of their data-analysis system. The program can be altered to interface with event recorders of different designs or with recorders of other behavioral events.

The terms experiment, treatment, replicate, record, recording, and flight are used to explain the versatility of the program and the punching of computer cards. An experiment is composed of one or more separate recordings. The major difference between experiments is a significant change in the data-gathering conditions that necessitate altering the parameters set by the data cards. Each experiment is divided into treatments and replicates. A replicate consists of a single mill, and a treatment is composed of a group of mills having insects representing a common test parameter fastened to the mills. An individual recording starts when the event recorder commences to record and ends when either the stop button or the stop and file gap buttons are pressed. The event recorder automatically places a space on the computer tape at the end of each 1 min of recording. A record consists of the data between these spaces. Each recording is analyzed separately, and the number and length of the individual recordings placed onto a single tape are limited only by the length of the tape and the flight ability of the insects. A flight is defined as a period of activity not interrupted by a rest period longer than 2.5 sec. However, this definition can be varied.

Figure 1 (A) Output produced at the beginning of each recording; (B) General treatment analysis.

PARAMETERS SET BY THE CONTROL CARD							
1.	EXPERIMENTS ON THE TAPE = 1						
2.	MILLS IN OPERATION = 9						
3.	TREATMENTS WITHIN THE MILLS IN OPERATION = 1						
4.	SEPARATE RECORDINGS ON THE TAPE = 1						
5.	FLIGHT LENGTH AND TIME DETERMINATOR (SEC) = 2.50						
6.	LENGTH OF MILL ARM (CM) = 21.55						
7.	INCREMENT (MIN) FOR FLIGHT LENGTH INTERVALS = 1						
8.	INCREMENT (METERS) FOR FLIGHT DISTANCE INTERVALS = 2						
9.	INCREMENT (METERS/MIN) FOR FLIGHT VELOCITY INTERVALS = 10						
10.	MILLS IN EACH TREATMENT DETERMINED BY THE COMPUTER						
11.	MINIMUM PERCENT TIME FLYING FOR INCLUSION IN THE DESCRIPTIVE STATISTICS = 5.						
12.	DESCRIPTIVE STATISTICS PRODUCED						
13.	DATA FROM MILLS NOT PUNCHED ON CARDS						
14.	NUMBER OF 1 MINUTE RECORDS ANALYZED FOR EACH RECORDING = 180						
15.	LENGTH (MIN) OF TIME INTERVALS = 10						

STATISTICS FOR THIS RECORDING							
1.	NUMBER OF 1 MINUTE RECORDS READ = 182						
	GOOD RECORDINGS = 180						
	BAD RECORDINGS = 2						
2.	MILLS ELIMINATED FROM THE STATISTICAL ANALYSIS						
	MILL NUMBER						
	1						

B							
FLIGHT MILL STUDIES							
PRINCIPAL INVESTIGATOR(S) - T. R. ASHLEY, J. L. SHARP, AND D. L. CHAMBERS							
LOCATION - INSECT ATTRACTANTS, BEHAVIOR, AND BASIC BIOLOGY RESEARCH LABORATORY							
GAINESVILLE, FLORIDA 32604							
NAME OF INSECT - ANASTREPHA SUSPENSUS (LOEW), CARIBBEAN FRUIT FLY							
EMERGENCE DATE - AUG 6, 1975							
TEST DATE - AUG 16, 1975							
TEST TIMES - BEGINNING 0900 ENDING 1200							
EXPERIMENT NUMBER - 198							
TAPE NUMBER - FF003							
TEMPERATURE - 27 DEG CEN							
RELATIVE HUMIDITY - 70							
LIGHT INTENSITY - 400 FT-C							
BAROMETRIC PRESSURE - 29.62							
TREATMENT - VIRGIN FEMALES, 10 DAYS OLD, NOT IRRADIATED							
RECORDING NO. 1 OF 1 RECORDING(S)							
TREATMENT NO. 1							

MILL NUMBER	TIME IN MINUTES FLYING	TIME IN MINUTES RESTING	PERCENT OF TIME FLYING	PERCENT OF TIME RESTING	TOTAL REVOLUTIONS	DISTANCE FLOWN (M)	OVERALL FLIGHT VELOCITY (M/MIN)
** 1	0.0	180.00	0.0	100.00	0	0.0	0.0
2	97.21	82.79	54.00	46.00	4997	3384.39	34.82
3	17.29	162.71	9.61	90.39	1047	709.12	41.01
4	17.79	162.21	9.88	90.12	846	572.98	32.21
5	86.92	93.08	48.29	51.71	6172	4180.20	48.09
6	29.00	151.00	16.11	83.89	1592	1078.24	37.18
7	86.46	93.54	48.03	51.97	4810	3257.74	37.68
8	74.75	105.25	41.53	58.47	4233	2866.95	38.35
9	113.63	66.38	63.12	36.87	6716	4548.64	40.03
SUM	523.04	916.96	290.58	509.42	30413.00	20598.26	309.37
MEAN	65.38	114.62	36.32	63.68	3801.63	2574.78	38.67
VARIANCE	1462.46	1462.46	451.38	451.38	4521456.00	2486907.00	22.30
STAND DEV	38.24	38.24	21.25	21.25	2328.40	1576.99	4.72
STAND ERROR	13.52	13.52	7.51	7.51	823.21	557.55	1.67
95 PER CONF INT	26.50	26.50	14.72	14.72	1613.50	1092.80	3.27
COEFF VAR	0.58	0.33	0.58	0.33	0.61	0.61	0.12
RANGE	96.33	96.33	53.52	53.52	5870.00	3975.66	15.89

A

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 RECORDING NO. 1 OF 1 RECORDING(S)
 TREATMENT NO. 1

FREQUENCY DISTRIBUTION FOR FLIGHT DURATIONS (MIN)																					
MILL NUMBER	GE LT 1	0 2	GE LT 2	1 3	GE LT 3	2 4	GE LT 4	3 5	GE LT 5	4 6	GE LT 6	5 7	GE LT 7	6 8	GE LT 8	7 9	GE LT 9	8 10	9 10	GT 10	TOTAL
** 1	0		0		0		0		0		0		0		0		0		0		0
2	33		7		5		1		0		0		0		0		0		0		48
3	40		0		0		0		0		0		0		0		0		0		41
4	48		2		0		0		0		0		0		0		1		0		51
5	5		1		0		0		0		0		0		0		0		0		7
6	64		2		1		1		0		0		0		0		0		0		69
7	21		3		0		1		0		0		0		0		0		1		27
8	21		2		0		0		0		0		0		0		0		0		25
9	4		0		2		1		0		0		1		1		1		2		16
SUM	236.00		17.00		8.00		4.00		0.0		0.0		1.00		1.00		2.00		3.00		284.00
MEAN	29.50		2.13		1.00		0.50		0.0		0.0		0.13		0.13		0.25		0.38		35.50
VARIANCE	435.71		4.98		3.14		0.29		0.0		0.0		0.13		0.13		0.21		0.55		417.71
STAND DEV	20.87		2.23		1.77		0.53		0.0		0.0		0.35		0.35		0.46		0.74		20.44
STAND ERROR	7.38		0.79		0.63		0.19		0.0		0.0		0.13		0.13		0.16		0.26		7.23
95 PER CONF INT	14.46		1.55		1.23		0.37		0.0		0.0		0.24		0.24		0.32		0.52		14.16
COEFF VAR	0.71		1.05		1.77		1.07		0.0		0.0		2.83		2.83		1.85		1.98		0.58
RANGE	60.00		7.00		5.00		1.00		0.0		0.0		1.00		1.00		1.00		2.00		62.00
GE = GREATER THAN OR EQUAL TO														LT = LESS THAN				GT = GREATER THAN			

GE = GREATER THAN OR EQUAL TO

LT = LESS THAN

GT = GREATER THAN

Output. The page of output produced at the start of each new recording consists of two sections (Figure 1A). The first defines and lists each of the parameters set by the data cards and should be examined carefully if the program was terminated by the computer or if the output was not of the desired format because an error on these cards may be responsible. The second section indicates the number of good and bad 1-min records read from the recording and lists the mills eliminated from the descriptive statistics because of insufficient activity.

The first 2 pages of the 20 pages of output produced for each treatment present a general analysis of the entire recording. The first page (Figure 1B) lists for each mill the time (minutes) flying and resting, percent time flying and resting, total revolutions, distance flown (meters), and overall flight velocity (meters/minute). The overall flight velocity is calculated by dividing the total flying time (minutes) into the total distance flown (meters) during the recording. The second page (not illustrated, but having the same general format) presents an analysis of the individual flight having the greatest overall velocity (meters/minute). This velocity is calculated by dividing the duration of the flight into the distance flown. In addition to giving the velocity for this flight, the computer calculates the flight's duration, number, time of occurrence, distance flown (meters), and number of revolutions. If the value "3" is given as the "flight number," the third flight of all the separate flights recorded for that insect had the greatest overall velocity. The "time of occurrence" is the amount of time from the start of the recording to the start of the flight.

B

FLIGHT MILL STUDIES

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 LIGHT INTENSITY - 400 FT-C
 BAROMETRIC PRESSURE - 29.62

TREATMENT - VIRGIN FEMALES, 10 DAYS OLD, NOT IRRADIATED
 RECORDING NO. 1 OF 1 RECORDING(S)
 TREATMENT NO. 1

DISTANCE FLOWN FOR EACH MILL DURING CONSECUTIVE 10 MINUTE TIME INTERVALS

	TIME INTERVAL (MIN)									
		1	2	3	4	5	6	7	8	9
GT 0 LE 10	0.	556.	513.	344.	547.	497.	492.	493.	545.	
GT 10 LE 20	0.	467.	105.	72.	519.	270.	272.	422.	266.	
GT 20 LE 30	0.	414.	24.	58.	509.	167.	425.	400.	429.	
GT 30 LE 40	0.	383.	28.	55.	505.	62.	412.	363.	0.	
GT 40 LE 50	0.	339.	9.	22.	469.	17.	394.	353.	0.	
GT 50 LE 60	0.	210.	7.	18.	454.	24.	367.	350.	0.	
GT 60 LE 70	0.	173.	6.	0.	435.	14.	322.	307.	0.	
GT 70 LE 80	0.	104.	3.	0.	431.	6.	276.	72.	397.	
GT 80 LE 90	0.	123.	4.	3.	236.	8.	125.	48.	404.	
GT 90 LE 100	0.	9.	3.	1.	0.	1.	29.	20.	291.	
GT 100 LE 110	0.	0.	2.	0.	0.	1.	0.	15.	338.	
GT 110 LE 120	0.	0.	0.	0.	0.	1.	30.	0.	177.	
GT 120 LE 130	0.	0.	0.	0.	1.	0.	51.	14.	154.	
GT 130 LE 140	0.	287.	0.	0.	2.	7.	26.	5.	333.	
GT 140 LE 150	0.	203.	1.	0.	0.	2.	0.	4.	286.	
GT 150 LE 160	0.	0.	1.	0.	0.	1.	1.	0.	354.	
GT 160 LE 170	0.	0.	1.	0.	0.	0.	35.	0.	247.	
GT 170 LE 180	0.	114.	2.	1.	71.	0.	2.	0.	326.	

GT = GREATER THAN

LE = LESS THAN OR EQUAL TO

Figure 2. (A) Frequency distribution for flight durations (minutes); (B) Time interval analysis for distance flown (meters).

The next six pages of output consist of frequency and percentage distributions. The first of these pages, the frequency distribution for flight durations, is illustrated in Figure 2A. The next page of output which also analyzes flight durations has the same format except that the frequencies in each column shown in Figure 2A are converted into percentages. The remaining four pages present an analysis of flight distances and velocities and have the same general format as described for flight durations.

The remaining 12 pages of output present an analysis of the insects' flight activity with respect to time. This analysis is accomplished by dividing the duration of each recording into specified intervals. For each interval and mill in operation, the computer calculates the number of flights, distance flown (Figure 2B), amount of time flying, percent of each interval spent in flight, percent of the total time flying, and the overall flight velocity. The output for these calculations requires six pages. The other six pages give the descriptive statistics (same as those shown in the bottom portion of Figures 1B and 2A, but arranged in a different format) for each of the above-cited variables.

A set of computer cards can be produced as part of the output on which the data for each mill and time interval have been punched. Recording these data on computer cards permits use of statistical programs available at most computer centers (Dixon, 1973; Nie, Bent, & Hull, 1970; Service, 1972) and provides a permanent and easy-to-store record of the analyzed data.

As the data from each 1-min record are read from the tape, the computer checks to see if a recording error has occurred. If an error is found, printed output is produced which indicates the location of the error on the tape. A recording error may result from a bad spot on the tape, a dirty tape, or a malfunction in the event recorder. Records containing errors are not included in the analysis.

Availability. A copy of this program punched on cards and an example of its output can be sent to interested individuals by contacting the senior author. No charge will be made for this service. The program will be sent as a "source" deck without job control language (JCL) cards.

REFERENCES

- CHAMBERS, D. L., SHARP, J. L., & ASHLEY, T. R. Tethered insect flight: A system for automated data processing of behavioral events. *Behavior Research Methods & Instrumentation*, 1976, 8, 352-356.
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