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ETHOM: Event-Recording Computer Software for the Study of Animal Behavior

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ABSTRACT

Accuracy of data capturing is important for the study of animal behavior. ETHOM is a software package which makes the acquisition of the exact behavioral sequence and timing easy. In addition, a useful data analysis subroutine is also included. In the "Recording Data" function, the user can record behavior directly in the field by setting the time interval through the audio alarm function for time sampling of behavioral data. If the behavior is recorded on videotape, this program can also match its timing with the timing recorded on the videotape or the VCR counter, and the user can correct data directly or press a special key to perform editing functions corresponding to the VCR, including pause for timing, different playback speeds, and modifying previous records. Users can also continue recording data from previously saved data in the "Loading Data" function. Two methods of recording are provided, by pressing one key to input (GET-KEY method) or typing a string of keystrokes representing a behavior pattern as desired then pressing the ENTER key (KEY-IN method). The "Analyzing Data" function shows the duration and frequency of each behavior pattern, and the output file of the frequency contingency table. All saved files are in ASCII format and can be read by most commercial word processors and statistics programs. The "Information Analysis and Data Combination" function provides the values of parameters in information theory and allows file combination with "Contingency Table Output File", "Result Output File" or "Observational Data File". The program can be executed on any IBM-compatible computer.

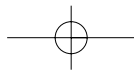
Key words: Event recorder, Computer program, Animal behavior, Video camera recorder, Information theory

INTRODUCTION

Many types of behavioral studies related to ethology, ecology, pharmacology, toxicology, psychology, and psychiatry, etc. need information of the behavior sequence and the duration of the behavior exhibited (Noldus et al., 1989). Many designs have been developed to obtain these data represented in alphabetical and numerical ways taken from the field or from videotapes. The most popular methods are check sheet, pen recorder, verbal description, and computer event recorder. Among them,

the computer event recorder can provide the most sophisticated operational functions because it can be modified according to the needs of the user. In the past, a computer event recorder had to exactly match the hardware, and it could provide only limited functions. The users also had to spend much time to facilitate the operation (Dawkin, 1971; White, 1971; Noldus, 1989). Nowadays users only need to devote themselves to writing software, and they can ignore the compatibility issue of hardware because of improvements in computers. Even a beginner can become acquainted

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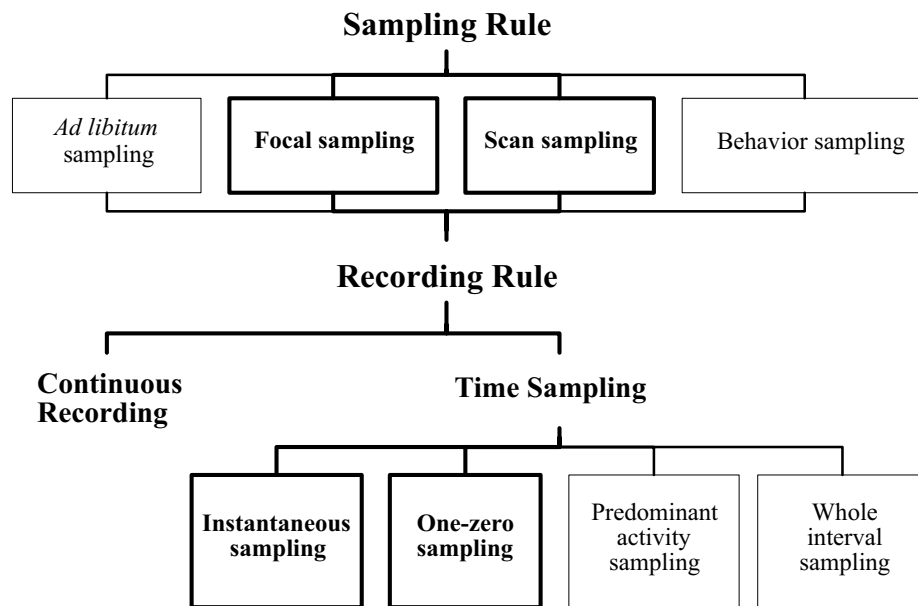


Figure 1. The relationship of sampling rules (determining who is watched and when) and recording (determining how their behavior is recorded) (Modified from Tyler, 1979; Martin and Bateson, 1993).

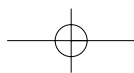
with the operation without special training. By this means, the study of animal behavior has become more convenient and efficient.

Compared to the inconvenience and lack of precision of traditional recording methods, e.g., timing by stop watch and recording data on a check sheet by hand, the adoption of a computerized event recorder program provides many advantages, e.g., the recording duration is more accurate, rapid behavior can be easily captured, and categories can be extended as needed. In addition, possible mistakes occurring during the transfer of original data from check sheets to numeric type will be much decreased (The time needed to correct these errors may be more than the time used to collect the data originally.) (Martin and Bateson, 1993). Unwin and Martin (1987) published a simple BASIC program for event recording for behavioral studies. Based on this program, one can write more suitable programs by oneself. However, this kind of software is not readily available from commercial dealers (except The Observer. Noldus Information Technology b. v., Costerweg 5, NL-6702 AA Wageningen, The

Netherlands; Phone 31-(0)8370-97677; Fax: 31-(0)8370-24496; e-mail: noldus@rcl.wau.nl).

The procedures of behavioral study are shown in Fig. 1. The first step is to define the behavioral categories, and the following steps are to determine the sampling rule and recording rule. The sampling rule is used to determine when to observe which individual. It consists of ad libitum, focal, scan, and behavior samplings (Martin and Bateson, 1993). Among these, the focal and scan samplings are frequently used. The recording rule is used to determine how to record behavior; it consists of continuous recording and time sampling. The latter can be divided into instantaneous, one-zero, predominant activity, and whole interval samplings (Tyler, 1979), and the former two are frequently used. The recording program provided by this report is for the recording rule. It is necessary for the user to define the behavior categories, and determine the sampling and recording rule before using this program.

In this report, a software package is provid-



Event-Recording Software for Behavior Studies

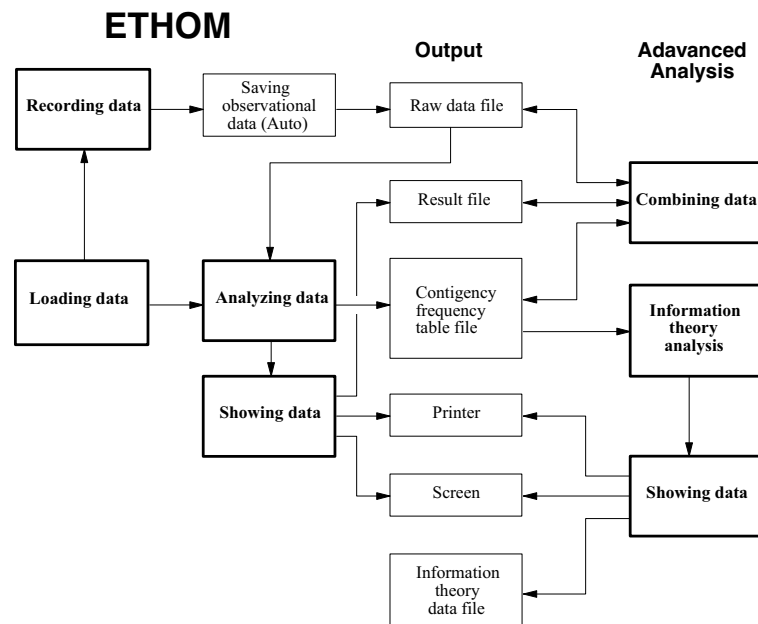


Figure 2. Flowchart representation of the main components of the ETHOM package. The left part is the basic data processing system and the right part is the advanced analysis. The middle is the output result, including output file, printer and screen preview. See text for each function of the main components.

ed for common conditions that one would encounter while recording behavioral events. It provides two recording methods that a user can select as needed, by either instantly pressing a key (GET-KEY method) or by entering a string of keystrokes of a behavior name (KEY-IN method). In addition, if recording is from a videotape, a user can select different playback speeds at which to record. This feature can allow users to detect very rapid events easily. It also provides a simple information theory program and a combination program for many data sets. This program is available through the internet (http://www.mbi.nsysu.edu.tw/~fiddler/ethom/intro_e.htm) as freeware or by a request to the senior author.

DESCRIPTION OF THE PACKAGE

Hardware requirements

Any IBM or 100% IBM-compatible computer, with a monochrome or color monitor

DOS version 2.0 or later (Microsoft Windows 95 or later is recommended)

At least 200 kilobytes (kb) base memory

At least one floppy disk drive or one hard disk drive

Language

The package is written in TRUE BASIC (Release 3.02) language. The advantages of this language include that it utilizes a rapid compiler, has good portability to different computers, and conforms to the American National Standard (the ANSI Standard) for Full BASIC. The disadvantages include those occurring in high-level microcomputer languages (including all BASIC languages). First, the execution speed is slow. Second, when the data related to time are processed, the accuracy is insufficient. Third, the computer timer is sometimes delayed by the sound produced. Although programs written in low-level microcomputer languages (e.g., machine code or assembler) can avoid these disadvantages, they are difficult to write and maintain. However, some limitations are not serious for general data recording. For example, the accuracy of the time function provided in the BASIC language is 0.01 s and

that should be sufficient for general observations (Unwin and Martin, 1987). If accuracy of timing is very critical, the user can cancel the sound function and use a stop watch instead. Besides, TRUE BASIC language contains a full range of modern programming structures, and the program can be easily understood and maintained.

Description of ETHOM

The main components of the ETHOM software package are represented in Fig. 2. This package is designed to allow the user to learn the operation as easily as possible and to prevent loss of data. The software can auto-detect the type of monitor, either monochrome or color, but the user can switch if necessary (e.g., use "REVERSE" for the gray level LCD (liquid crystal display) screen of portable computers (notebooks)). Users can see each parameter (including behavior name, timing, video timing, and sequences) on the screen immediately after pressing a key and can observe any input error. If a keystroke is erroneous, it can be corrected at once.

There are two types of measurements to describe a behavior pattern, i.e., event and state (Martin and Bateson, 1993). Event is a behavior pattern that occurs very quickly, and it is difficult to decipher its duration. State is a behavior pattern that lasts longer, and its duration can easily be deciphered. The duration of a state is the time from the beginning to the end of the behavior pattern. In this study, the behavior patterns of the KEY-IN method (see below) are state and those of the GET-KEY method have both patterns according to one's definition. In the GET-KEY method, the event is represented as a frequency (instances occurring totally) and rate (instances occurring per unit time); the state is represented as frequency and total duration. However, the behavioral state in the KEY-IN method is different from that in the GET-KEY method. In the former method, a state is defined as the time from when the first character of the proceeding behavior is pressed to the time when the first

character of the following pattern is pressed ("mutually exclusive" of Noldus, 1991), i.e., the duration of the behavioral state is the time between the initial point of two consecutive patterns. In the GET-KEY method, one must press the same key two times to obtain a complete state—the first time is the beginning, and the second time is the end of the pattern. Users can record many patterns simultaneously, i.e., the patterns are "nonexclusive" (Noldus, 1991).

For illustrating the use of ETHOM, a dummy example of a mirror display of a fish is provided (Fig. 3a-f).

All files created with this software are ASCII files. They can be edited by any personal editor and are readable by most statistical software. However, if the length of one row exceeds 255 characters, the row can not be completely read by certain editors. In the initial rows, above the data matrix, users can add any number of rows of notes and empty rows. Each row of notes must be marked with an asterisk (*) at the beginning; the program will ignore this row during reading. A row with two or more asterisks at the beginning must be treated more carefully, because some information and formatting are included in this part. It is suggested to be used to modify the data and for comments only, while other parts of the file must be kept intact.

Observational Data File: Data of each behavior pattern in a sequence is stored as one row, and the row consists of five items. The first column is the name of a behavior pattern, the second is the time of initiation from the start of a observation, the third is the TV time if the user sets it, the fourth is the playback speed, and the fifth is the order of this record (Fig. 3b-c). If the data is recorded by the GET-KEY method and this behavior pattern is a state, then there is an additional sixth column that stores the information of the start (1) or the end (0) of this state. The last row of the file stores the information of the stop time and the definition of the type of the GET-KEY method (see "Recording Data" section).

Keystroke Definition File: This file is used

Event-Recording Software for Behavior Studies

(a)

- A Aggression
- C Cross_tail
- D Display
- E Escape
- F Fighting

(b)

```
* *****
* ***** --- 20000504 *****
* *****
```

| | | | | |
|---|-------|----------|---|----|
| A | 1.87 | 00:00:01 | 1 | 1 |
| E | 3.73 | 00:00:03 | 1 | 2 |
| F | 4.01 | 00:00:04 | 1 | 3 |
| D | 4.34 | 00:00:04 | 1 | 4 |
| C | 4.83 | 00:00:04 | 1 | 5 |
| E | 5.22 | 00:00:05 | 1 | 6 |
| A | 5.49 | 00:00:05 | 1 | 7 |
| D | 5.82 | 00:00:05 | 1 | 8 |
| F | 6.15 | 00:00:06 | 1 | 9 |
| E | 6.42 | 00:00:06 | 1 | 10 |
| A | 6.75 | 00:00:06 | 1 | 11 |
| D | 6.97 | 00:00:07 | 1 | 12 |
| C | 7.25 | 00:00:07 | 1 | 13 |
| E | 7.63 | 00:00:07 | 1 | 14 |
| F | 7.96 | 00:00:07 | 1 | 15 |
| D | 8.84 | 00:00:08 | 1 | 16 |
| E | 9.06 | 00:00:09 | 1 | 17 |
| C | 9.83 | 00:00:09 | 1 | 18 |
| F | 10.32 | 00:00:10 | 1 | 19 |
| A | 10.65 | 00:00:10 | 1 | 20 |
| C | 11.26 | 00:00:11 | 1 | 21 |
| F | 12.08 | 00:00:12 | 1 | 22 |
| E | 12.41 | 00:00:12 | 1 | 23 |
| A | 12.74 | 00:00:12 | 1 | 24 |
| D | 13.18 | 00:00:13 | 1 | 25 |
| C | 13.51 | 00:00:13 | 1 | 26 |
| F | 13.73 | 00:00:13 | 1 | 27 |
| E | 13.89 | 00:00:13 | 1 | 28 |
| A | 14.22 | 00:00:14 | 1 | 29 |
| D | 14.50 | 00:00:14 | 1 | 30 |
| E | 14.83 | 00:00:14 | 1 | 31 |
| F | 15.05 | 00:00:15 | 1 | 32 |
| A | 15.38 | 00:00:15 | 1 | 33 |
| D | 15.65 | 00:00:15 | 1 | 34 |
| E | 15.87 | 00:00:15 | 1 | 35 |
| F | 16.15 | 00:00:16 | 1 | 36 |
| A | 16.53 | 00:00:16 | 1 | 37 |
| E | 16.86 | 00:00:16 | 1 | 38 |
| D | 17.08 | 00:00:17 | 1 | 39 |
| E | 17.46 | 00:00:17 | 1 | 40 |
| A | 17.85 | 00:00:17 | 1 | 41 |
| D | 18.07 | 00:00:18 | 1 | 42 |
| E | 18.23 | 00:00:18 | 1 | 43 |
| C | 18.78 | 00:00:18 | 1 | 44 |

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| | | | | | |
|----------|-------|----------|---|----------|---|
| F | 19.00 | 00:00:19 | 1 | 45 | |
| E | 19.22 | 00:00:19 | 1 | 46 | |
| A | 19.50 | 00:00:19 | 1 | 47 | |
| D | 19.66 | 00:00:19 | 1 | 48 | |
| C | 19.94 | 00:00:19 | 1 | 49 | |
| F | 20.21 | 00:00:20 | 1 | 50 | |
| E | 20.54 | 00:00:20 | 1 | 51 | |
| A | 20.76 | 00:00:20 | 1 | 52 | |
| D | 20.92 | 00:00:20 | 1 | 53 | |
| F | 21.53 | 00:00:21 | 1 | 54 | |
| C | 21.80 | 00:00:21 | 1 | 55 | |
| D | 22.08 | 00:00:22 | 1 | 56 | |
| A | 22.30 | 00:00:22 | 1 | 57 | |
| E | 22.41 | 00:00:22 | 1 | 58 | |
| D | 22.68 | 00:00:22 | 1 | 59 | |
| end_time | 23.34 | 00:00:23 | 1 | 00:00:00 | 1 |

(c)

* *****
 * ***** --- 20000504 *****
 * *****

| | | | | |
|------------|-------|----------|---|----|
| Aggression | 1.87 | 00:00:01 | 1 | 1 |
| Escape | 3.73 | 00:00:03 | 1 | 2 |
| Fighting | 4.01 | 00:00:04 | 1 | 3 |
| Display | 4.34 | 00:00:04 | 1 | 4 |
| Cross_tail | 4.83 | 00:00:04 | 1 | 5 |
| Escape | 5.22 | 00:00:05 | 1 | 6 |
| Aggression | 5.49 | 00:00:05 | 1 | 7 |
| Display | 5.82 | 00:00:05 | 1 | 8 |
| Fighting | 6.15 | 00:00:06 | 1 | 9 |
| Escape | 6.42 | 00:00:06 | 1 | 10 |
| Aggression | 6.75 | 00:00:06 | 1 | 11 |
| Display | 6.97 | 00:00:07 | 1 | 12 |
| Cross_tail | 7.25 | 00:00:07 | 1 | 13 |
| Escape | 7.63 | 00:00:07 | 1 | 14 |
| Fighting | 7.96 | 00:00:07 | 1 | 15 |
| Display | 8.84 | 00:00:08 | 1 | 16 |
| Escape | 9.06 | 00:00:09 | 1 | 17 |
| Cross_tail | 9.83 | 00:00:09 | 1 | 18 |
| Fighting | 10.32 | 00:00:10 | 1 | 19 |
| Aggression | 10.65 | 00:00:10 | 1 | 20 |
| Cross_tail | 11.26 | 00:00:11 | 1 | 21 |
| Fighting | 12.08 | 00:00:12 | 1 | 22 |
| Escape | 12.41 | 00:00:12 | 1 | 23 |
| Aggression | 12.74 | 00:00:12 | 1 | 24 |
| Display | 13.18 | 00:00:13 | 1 | 25 |
| Cross_tail | 13.51 | 00:00:13 | 1 | 26 |
| Fighting | 13.73 | 00:00:13 | 1 | 27 |
| Escape | 13.89 | 00:00:13 | 1 | 28 |
| Aggression | 14.22 | 00:00:14 | 1 | 29 |
| Display | 14.50 | 00:00:14 | 1 | 30 |
| Escape | 14.83 | 00:00:14 | 1 | 31 |
| Fighting | 15.05 | 00:00:15 | 1 | 32 |
| Aggression | 15.38 | 00:00:15 | 1 | 33 |
| Display | 15.65 | 00:00:15 | 1 | 34 |

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| | | | | |
|------------|-------|----------|---|----|
| Escape | 15.87 | 00:00:15 | 1 | 35 |
| Fighting | 16.15 | 00:00:16 | 1 | 36 |
| Aggression | 16.53 | 00:00:16 | 1 | 37 |
| Escape | 16.86 | 00:00:16 | 1 | 38 |
| Display | 17.08 | 00:00:17 | 1 | 39 |
| Escape | 17.46 | 00:00:17 | 1 | 40 |
| Aggression | 17.85 | 00:00:17 | 1 | 41 |
| Display | 18.07 | 00:00:18 | 1 | 42 |
| Escape | 18.23 | 00:00:18 | 1 | 43 |
| Cross_tail | 18.78 | 00:00:18 | 1 | 44 |
| Fighting | 19.00 | 00:00:19 | 1 | 45 |
| Escape | 19.22 | 00:00:19 | 1 | 46 |
| Aggression | 19.50 | 00:00:19 | 1 | 47 |
| Display | 19.66 | 00:00:19 | 1 | 48 |
| Cross_tail | 19.94 | 00:00:19 | 1 | 49 |
| Fighting | 20.21 | 00:00:20 | 1 | 50 |
| Escape | 20.54 | 00:00:20 | 1 | 51 |
| Aggression | 20.76 | 00:00:20 | 1 | 52 |
| Display | 20.92 | 00:00:20 | 1 | 53 |
| Fighting | 21.53 | 00:00:21 | 1 | 54 |
| Cross_tail | 21.80 | 00:00:21 | 1 | 55 |
| Display | 22.08 | 00:00:22 | 1 | 56 |
| Aggression | 22.30 | 00:00:22 | 1 | 57 |
| Escape | 22.41 | 00:00:22 | 1 | 58 |
| Display | 22.68 | 00:00:22 | 1 | 59 |
| end_time | 23.34 | 00:00:23 | 1 | 1 |

(d)

```

* *****
* ***** --- 20000504 *****
* *****
*=> The result is come from the file: DEMO.DAT
*=> The result is stored as the file: DEMO_RST.DAT
*=> The duration of session: 0 min 23.34 sec
*=> The number of observations: 59
**EVENT      Frequency      Rate(1/min)
*-----
Aggression      12      30.848329
Cross_tail      8      20.565553
Display         13      33.419023
Escape          15      38.560411
Fighting        11      28.277635
    
```

(e)

```

* *****
* ***** --- 20000504 *****
* *****
**Aggression   Cross_tail   Display     Escape     Fighting
0              1            8           3          0
0              0            1           2          5
1              4            0           5          2
7              2            2           0          4
3              1            2           5          0
    
```

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(f)

* *****
 * ***** --- 20000506 *****
 * *****

DATE is: 20000506 TIME is: 10:44:27
 the original data file is: DEMO_INF.DAT
 the result output to file: DEMO_INF.RST
 the original data matrix: 5 x 5

| | Aggressio | Cross_tai | Display | Escape | Fighting | |
|------------|------------------|------------------|------------------|------------------|------------------|---------------|
| Aggression | 0.000 (2.276) | 1.000 (1.655) | 8.000 (2.690) | 3.000 (3.103) | 0.000 (2.276) | 12.000 |
| Cross_tail | 0.000 (1.517) | 0.000 (1.103) | 1.000 (1.793) | 2.000 (2.069) | 5.000 (1.517) | 8.000 |
| Display | 1.000 (2.276) | 4.000 (1.655) | 0.000 (2.690) | 5.000 (3.103) | 2.000 (2.276) | 12.000 |
| Escape | 7.000 (2.845) | 2.000 (2.069) | 2.000 (3.362) | 0.000 (3.879) | 4.000 (2.845) | 15.000 |
| Fighting | 3.000 (2.086) | 1.000 (1.517) | 2.000 (2.466) | 5.000 (2.845) | 0.000 (2.086) | 11.000 |
| | | 11.000 | 8.000 | 13.000 | 15.000 | 11.000 58.000 |

```

+-----+
| chi-square          =    49.541487 |
| d.f.                =     16      |
+-----+
| alpha              =    0.000027*** |
+-----+
    
```

**If the value > table's value, or < -(table's value), then REJECT H(0).

NOTE
 the percent of E value < 1 = 0.00 %
 the percent of E value < 5 = 100.00 %

**If any E frequency is < 1 or more than 20% < 5, the chi-square test is not suitable!

*Partitioning X2 matrix of the effect of preceding act:
 ^^^^^^^^^^^^^^^

(d.f.= 4)

| ETHOGRAM | X2 value | alpha |
|------------|----------|-----------|
| Aggression | 19.290 | 0.001 *** |
| Cross_tail | 12.723 | 0.013 * |
| Display | 9.985 | 0.041 * |
| Escape | 14.799 | 0.005 ** |
| Fighting | 5.409 | 0.248 |

+*Partitioning X2 matrix of the dyad frequency:
 ^^^^^^^^^^^^^^^

(d.f.= 1)

| | Aggressi | Cross_ | Display | Escape | Fighting |
|------------|-----------|--------|-----------|---------|-----------|
| Aggression | 3.54- | 0.38- | 17.04+*** | 0.01- | 3.54- |
| Cross_tail | 2.17- | 1.48- | 0.52- | 0.00- | 11.44+*** |
| Display | 1.11- | 4.86+* | 4.37-* | 1.97+ | 0.05- |
| Escape | 10.10+*** | 0.00- | 0.96- | 7.06-** | 0.78+ |

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```

Fighting      0.61+   0.25-   0.14-   2.72+   3.18-
*** Information Content ***
^^^^^^^^^^^^^^^^^^^^
H(a)   =   2.294   (bias correction is   2.344)
H(b)   =   2.292   (bias correction is   2.342)
H(a,b) =   3.893
H(b/a) =   1.598   (bias correction is   1.847)
H(a/b) =   1.600   (bias correction is   1.849)
H(t)   =   0.694   (bias correction is   0.495)
*** Transmission Efficiency (TE) ***
^^^^^^^^^^^^^^^^^^^^
      for _a_ = 30.24 percent
      for _b_ = 30.27 percent
*** Variance ***
^^^^^^^^
var H(a)   =  -0.0027
var H(b)   =  -0.0026
var H(b/a) =  -0.0026
var H(a/b) =  -0.0028
var H(t)   =   0.0150

```

Figure 3. A dummy example of a mirror display of a fish illustrating the use of ETHOM with one individual in the GET-KEY recording method. A fish is displaying before a mirror.

- (a) Five behavioral categories (events) are defined and five keystrokes are assigned to these categories for the GET-KEY method (stored in the Keystroke Definition File, KEY_DEF.DAT). The characters of keystrokes (the first column) are replaced by complete names (the second column) by this file during analysis.
- (b) A period of observation (23.34 s) is recorded, and the data are stored in an Observational Data File, DEMO.DAT).
- (c) The keystrokes of categories of the file are changed to complete categories in "Analyzing Data" function and stored in DEMO2.DAT.
Each row is a record, and there are 59 records in this example (see Fig. 3d). The first column is the name of the pattern, which must be a complete word, i.e., no spaces are allowed in the name, but the user can use other symbols to connect two words, e.g., the "_" in "Cross_tail". The second column is the time passed since the start. The third column is the time corresponding to the TV time displayed if user has set it. The fourth column is the playback speed, and the fifth column is the order of this record.
- (d) The result of analysis is stored in the Result Output File, DEMO_RST.DAT, by the "Showing Data" function which shows the frequencies of each event.
- (e) The Contingency Table Output File, DEMO_INF.DAT, is produced in the "Analyzing Data" function and is read by the "Information Analysis and Data Combination" function.
- (f) Information measurements are computed in the "Information Analysis and Data Combination" function, and the result is stored in the Information Analysis Output File, DEMO_INFRST. It includes the original value and expected value of the data in a contingency table, chi-square test, partitioning chi-square matrix of the effect of the preceding act and the dyad frequency, information content, transmission efficiency, and variance. For details of these measurement, one should refer to other references (e.g., Dingle, 1972; Steinberg, 1977; Losey, 1978).

to replace the character of behavior pattern in the GET-KEY method with a complete behavioral name. It contains two columns: the first is the character to be replaced, and the second is the complete name of the behavior (Fig. 3a). There is at least one space between the two columns, and the name of the behavior should be a whole word with no spaces.

Result Output File: The content of the file may be somewhat different according to the recording method used. The resulting report contains the duration of a session, the number of behavioral patterns recorded, categories, frequency, and total duration (for the STATE) or rate (1/min) (for the EVENT) (Fig. 3d).

Contingency Table Output File: This file is provided in "Analyzing Data" function and can be read by the "Information Analysis" function. The first row that begins with two asterisks (**) is for the names of the behavior patterns; the other part is the matrix for the measurement of information theory (Fig. 3e).

Information Analysis Output File: In the "Information Analysis" function, the calculation of the measurement (or parameters) of information theory is processed, and the results can be stored in an Information Analysis Output File. The content of the file includes: the original value and expected value of the data in a contingency table, chi-square test, partitioning chi-square matrix of the effect of the preceding act and the dyad frequency, information content, transmission efficiency, and variance (Fig. 3f). For details of the measurement of information theory, one should refer to other relevant references (e.g., Dingle, 1972; Steinberg, 1977; Losey, 1978).

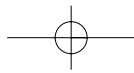
1. Recording Data

There are two methods to input observational data. One is GET-KEY (Fig. 4a). A user presses a character that immediately shows up on the screen, including 10 numerical and 26 alphabetical keys. The time and this key are also stored in memory automatically. This method is suitable for behavior patterns which occur very rapidly, and are only limited by the

user's response between the eyes and fingers. A user can define four types of keyboards with GET-KEY: (1) 0-9 is STATE and A-Z is EVENT; (2) 0-9 is EVENT and A-Z is STATE; (3) 0-9 and A-Z all are EVENT; and (4) 0-9 and A-Z all are STATE (see above for the definition of event and state).

Also, there is the KEY-IN method (Fig. 4b), which provides more versatile ways to record behavioral sequences, but even it has difficulty handling behavior patterns which occur too rapidly. The user types strings of keystrokes of behavioral categories. The program will freeze the time when the first character was pressed and will store it when ENTER is pressed. If a user wants to annotate some information, first press "\", then type the words directly. This method is suitable for time sampling or sampling for behavior patterns which do not occur very frequently. Its advantages include a longer behavioral category, the absence of limitation of the number of categories, and the ability to annotate information on-line. The type of behavior pattern of KEY-IN is STATE, and the duration is the time between two consecutive behavior patterns. Any ASCII characters, excluding the space character (a space will be replaced by "_" automatically), can be typed as categories in this method, but the length is limited by the screen width (59 characters).

There is some important information shown on the screen during recording. It consists of the present date and time, the time from the beginning of the observation, and TV timing to match the timing recorded on the videotape. All characters pressed can be monitored on the screen to avoid input error. In the GET-KEY method, each key pressed shows as a different color. If the behavior pattern is STATE, the character on the screen will remain blinking and color-highlighted until the same key is pressed the next time. While many behavior patterns are being recorded, it is convenient to check which STATE patterns are still being processed by this function. There is a value in the left lower corner of the screen showing the memory remaining. If the remain-



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a

```

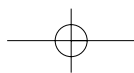
LOAD from:          RECORDING DATA          SAVE as: UNNAMED.
DATE=20000506
TIME=13:51:59
NOW=13:53:59
PAUSE 0/1=F10
SAVE DATA=F2
STOP= ESC
                                107.38
                                00:01:47.32
                                E
                                134
STATES= 1 2 3 4 5 6 7 8 9 0
EVENTS= Q W E R T Y U I O P
                                104.14
                                00:01:44
Free Memory
(bytes)= 428608
                                TV Start: 00:00:00
                                TV Timing:00:01:47
                                Press a character (0-9 and A-Z) to input.
ALT-S SOUND: ON          ALT-R RESET RECORDING
    
```

b

```

LOAD from:          RECORDING DATA          SAVE as:
DATE=19980517
TIME=15:00:50
NOW=15:03:10
PAUSE 0/1=F10
STOP= ESC
                                6-> Fighting          40.92          118.75
                                7-> Fighting          43.83          00:01:58.75
                                8-> Aggression          47.12
                                9-> Biting          53.93
                                10-> Escape          57.12
                                11-> Escape          59.21
                                12-> Biting          65.80
                                13-> Collapsing          67.83
                                14-> Cross_tail          72.88
                                15-> Biting          79.04
                                16-> Aggression          86.94
                                17-> Escape          92.60
                                18-> Body_shaking          108.09
                                19-> Display          114.74
                                20->
Free Memory
(bytes)= 371904
                                TV Start: 00:09:00
                                TV Timing:00:10:58
                                Type a string of characters, THEN ENTER
                                INS
                                ==> Biting
ALT-S SOUND: ON          ALT-R RESET RECORDING
    
```

Figure 4. Examples of two types of recording methods of ETHOM: (a) GET-KEY method. User presses a character that immediately shown on the screen, including 10 numerical and 26 alphabetical keys. User can define 0-9 and A-Z as STATE or EVENT, respectively. (b) KEY-IN method. User types the strings of keystrokes of behavioral categories then press ENTER to store it. The program will freeze the time when the first character was pressed.



ing memory is not enough, e.g., 100 kb, this value will blink and the user should save the recorded data immediately (by pressing the F2 function key). Otherwise the program will stop, and it will ask the user to save the data.

This program provides many ways of editing the data recorded on-line. If a user wants to correct the previous piece of data immediately, they should just press BACKSPACE which erases the entry; then they can modify this input. While processing this function, the timing continues. Therefore this function is suitable for behavior which does not occur frequently. If the observation is recorded from a videotape, an exact and conventional editing function is provided. If there is any input error, the user can press the pause key, F10, and all timing will be "frozen" except the current time, after which they can press the editing keystrokes. The BACKSPACE key is for deletion of previous records. A user can press BACKSPACE more than one time to the behavior pattern which needs correcting, and the timing on the screen will also change correspondingly. The LEFT or RIGHT key is for decreasing or increasing the timing of the system timer and TV timer; each press is 0.5 s. The "-" or "+" key decreases or increases the time of the TV timer; each press is 0.5 s. This function can synchronize the TV timer with the timing of the videotape. If the user wants to change the VCR playback speed, e.g., to watch rapid behavior patterns in slow display, pressing F9 sets the value of the playback speed; then press ENTER. The timing will be adjusted to the necessary speed and matched to the VCR playback speed. Users can utilize this function to analyze very quick motions in detail.

The program provides an audio alarm function that beeps at a given time interval when the user records in time sampling. In addition, each keystroke will produce a sound to remind the user during data recording. This function is suitable for the keyboard which is "silent". However, if the program is executed under DOS, or DOS shell in Windows 3.x, this alarm function will slow down the operational rate of

keystroke and the timing of the system to an unpredictable extent, especially under the system of Microsoft Windows 3.x. The longer the sound is produced, the slower will be the timing. If the sampling with an error of a few seconds are acceptable, then the alarm function is useful. Otherwise this function must be canceled and replaced with a separate timer by the user. The "silent" keyboard can also be replaced by the 101 keyboard which produces a small sound for each keystroke. If the audio alarm function is necessary and the timing must be accurate, it is recommended that the program should be run under Microsoft Windows 95 or later version. The audio alarms produced will not delay the timing, either executed in full screen or in DOS box. However, it is suggested that the behavior pattern be recorded in full screen with all other programs in Windows closed, otherwise the timing may be affected.

All the data recorded or analyzed are stored in memory, thus the execution speed will not be affected by disk writing. The electric power source must be stable, otherwise the data may be lost completely. However, because hard disks are cheaper now and the writing speed of hard disks is quicker, this program provides the function of manual saving (F2) and autosaving at given intervals during recording. In the beginning of the recording program, the user is asked to give a filename for saving data. If the filename is already taken, the program will ask the user whether or not to overwrite it. When the user stops recording and returns to the main menu, the data will be autosaved in the file name given by the user or in the file, "UNNAMED", by default. If many observational data sets need to be combined into a single file, the "Information Analysis and Data Combination" should be run.

2. Saving Observational Data

Although the observational data will be autosaved in a file when the user quits the recording program, the data can be saved in another file. Or the observational data can be

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saved in a separate file after "Loading Data".

3. Loading Data

Two types of observational data can be loaded into this system. One is the complete observational data which can be loaded for analysis. The other is incomplete data which can be loaded to continue to record starting from the last record.

4. Analyzing Data

In "Analyzing Data" function, if data is recorded by the GET-KEY method, the program will ask the user to type the filename of "Keystroke Definition File" (Fig. 3a) (see above) to change the keystrokes of categories to complete categories. If the Keystroke Definition File does not exist or some characters are not included, the program will use the original character during analysis. In addition, the program will ask the user whether or not to produce the "Contingency Table Output File" (Fig. 3e). The behavioral categories will also be transferred to the file. The resulting output can be sent to the printer, screen, or a file with the "Showing Data" function.

5. Showing Data

"Showing Data" sends the observational data and/or resulting output to the printer or screen, or stores the resulting output in a file (Fig. 3d). If many sets of "Result Output Files" need to be combined into a single file, the "Information Analysis and Data Combination" function should be selected.

6. Information Analysis and Data Combination

This function has two purposes: one is the calculation of the information measurement, and the other is the combination of the "Contingency Table Output File", "Result Output File", or "Observational Data File". In "Information Analysis", the output can be sent to the printer, screen, or a file (Fig. 3f). In the combination of "Observational Data Files", all records are combined and sorted into a complete sequence according to the time scale.

However, because keystrokes might not generally match accurately the occurrence of an event, if two events occur too close together, the combined sequence may not be true.

DISCUSSION

Traditional behavioral studies always depend on the descriptions of the process of behavioral phenomenon. However, this kind of description is easily influenced by subjective factors, and it is difficult to provide quantitative and comparable results for further studies. There were many statistical methods and mathematical models to quantify the behavioral data after 1975 when the symposium on "Quantitative Methods in Ethology" was held (Colgan, 1978). Studies of quantitative behavior were still difficult because of the inconvenience of recording media and the unpopularity of the computer. Now computers have advanced rapidly, and the collection, quantification, and analysis of numerical data have become very convenient. Therefore the results of behavioral studies are more convincing on the basis of large samples of data and reliable statistical methods. The basic data of most behavioral studies are the behavior sequence and timing of each behavior pattern. Therefore this program is designed for general application of recording behavioral data. After collecting those data, one can analyze them with more sophisticated statistical tools.

All kinds of DOS-based programs are limited to 640 kb of memory. In the DOS environment of Windows 95 or later version, ETHOM can manage about 1500 records without a problem. This limitation will be largely improved by rewriting the program with Windows 95-based language (e.g., True Basic version 5) in the future.

The objective of this program is focused on general behavioral studies. The accuracy of timing absolutely depends on the eyes and the response speed of keyboard strokes of the user. The program can express its powerful ability during the recording of observational data from slow VCR playback speed. Very rapid

behavioral patterns are easily recorded in detail. For the consideration of the delay of the keystroke and VCR playback, it is not recommended to execute special functional recording while many behavior patterns are continuously occurring, i.e., it is preferable to record a complete sequence without interruption. If the accuracy of timing is very important, we suggest that the user record the behaviors onto a videotape with "RC time code" (or "video time codes") by some model of video camera recorder (e.g., Sony TR2000 Hi8) or add them with a special device, then apply the appropriate event recording software and its video interface (e.g., The Observer 3.0, Visser, 1993; Wawra, 1994).

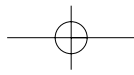
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ETHOM：應用於動物行為研究的事件記錄電腦軟體

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摘要

動物行為學的研究上，精確數據之獲得往往是實驗成功與否之關鍵所在，本軟體提供使用者一簡易方式以獲得正確的行為序列與精確的時間記錄，此外也提供實用的數據分析功能。在記錄數據功能上，可直接在現場記錄，也能夠配合時段採樣的時間間隔使用鬧鈴功能，也可以配合所拍攝錄影帶上的時間（或錄影機上顯示之時間）做同步記錄；修改功能方面，提供直接按鍵修改或按特殊功能鍵以配合錄影機的特殊功能，包括暫停，不同播放速度和連續多次修改記錄；可選擇單鍵即時記錄（GET-KEY）或鍵入行為名稱後按輸入鍵記錄（KEY-IN）；分析錄影帶時，本程式提供暫停計時、慢動作計時、記錄修改、銜接前次記錄等功能。在分析功能方面，除了可計算每一行為目錄的持續時間和發生頻率等基本數據之外，並可以把行為序列轉換成頻度關連表，再由STS程式讀取。STS程式除了可計算訊息理論中的相關數值之外，也能進行卡方分析。另外也可將數次分析之結果或數次行為事件合併成一個檔案以便於比較。使用時僅需IBM相容個人電腦即可執行本程式。

關鍵詞：事件記錄器、電腦程式、動物行為、錄影機、訊息理論

