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TECHNICAL NOTE

A Bar Code Scoring System for Behavioral Research

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A data collection method using lap-top computers and bar codes was developed and used in behavioral research. The studies involved several common sampling methods and a variety of study subjects. Advantages and restrictions of the system are discussed. Overall, we found bar code technology to increase both efficiency and accuracy of behavioral data collection.

Key words: portable computer, behavior, data collection

INTRODUCTION

In the past two decades, there has been a gradual progression in behavioral research away from checksheets towards event recorders and portable computers. Unfamiliarity with computers and a reluctance to abandon proven methods have often prevented researchers from adopting such newer methods. However, if these obstacles can be overcome, the advantages of computerized systems are well worth the effort. They include increased efficiency of data collection and analysis, more rapid transfer to permanent data bases, reduction of transcription errors, reduced volume of archived records and decreased data handling time [Flowers & Leger, 1982; Cooney, 1985; Unwin & Martin, 1987].

Bar codes have become a familiar part of our environment. They are used effectively in sales, inventory, manufacturing, and other applications where large amounts of information must be processed. Bar codes provide an easy and accurate means of data entry with minimal observer training and computer programming requirements. We have applied this technology to behavioral research, utilizing a variety of sampling methods and portable TRS-80 Model 100 and 102 computers. This article describes how we applied bar code technology and discusses advantages and restrictions of its use in behavioral research.

METHODS

Bar Codes

Bar code technology as described in Talbott & Parliman [1987] involves four major components: a bar code symbol, comprised of black lines and spaces of varying widths; a scanning device; a decoder; and a computer to process the coded

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information. In the bar code, alphanumeric characters and certain punctuation symbols are represented by specific sequences of lines and spaces. The individual components can be combined into words, numbers, or other meaningful expressions. The scanning device reads the bar code with an infrared sensor. Decoding software installed on the data entry computer translates the pattern into the original characters for subsequent processing and storage.

Hardware

In our study, we used the TRS-80 Model 100 lap-top computer and its successor, the Model 102 [Hensler et al., 1986]. To provide additional space for data, the memory on each computer was expanded to 32 kilobytes. A cassette recorder with EAR, AUX, and REM ports and a computer cassette interface cable were required to install the bar code decoding software onto the portable computer. The scanning device was a detachable TRS-80 digital wand. Data storage and analysis were carried out on Apple Macintosh Plus and SE microcomputers. A Hayes compatible modem cable with a null modem adapter enabled transfer of data directly from the portable TRS-80 to the Macintosh. High resolution bar codes were generated with a laser printer and placed under protective, self-adhesive photo album sheets.

Software

Many kinds of software applications are available to create bar codes on different computer systems. A flexible and simple system for the Macintosh was obtained through installation of a 'bar code' font into the system file. This approach allows any word processing software to produce documents containing bar codes. Software which enables the portable TRS-80 to decode bar codes was included with the scanner. Communications software was only necessary for the personal computer, as the TRS-80 has its own built-in program. A structured BASIC programming language on the Macintosh facilitated data processing and analysis.

Programs and Sampling Methods

We developed BASIC programs on the protable TRS-80 for two types of focal animal data collection (one-zero sampling and timed behaviors), and for a widely used combination of focal animal and periodic instantaneous or scan sampling (terminology follows Altmann [1974]). A variety of prompts, checks, and auditory cues were included in these programs to assist the user, facilitate data entry, and reduce errors in data collection. All programs provided a limited ability to correct errors while collecting data. Some of the programs allowed the observer to add notes at the end of the observation. The portable TRS-80's internal clock was used to determine times, as needed for each study. The study subjects were mainly primates, but also included cheetahs, elephants, and condors (see Fig. 1 for a sample bar code ethogram).

For all data collection methods, we chose to create detailed data files containing header information and data in raw or partially processed form (see Fig. 2 for a sample data file). This provided the most complete data files, and made them easier to understand, because they resembled traditional data collection forms. The files were later reformatted for analysis with a program on the microcomputer.

The programs designed for the collection of sequential focal animal data combined with scans were made as flexible as possible, allowing for virtually any format of sequential behaviors, including simultaneous or overlapping behaviors (e.g., ACTOR-BEHAVIOR-RECIPIENT, . . . or BEHAVIOR1, BEHAVIOR2, BEHAVIOR1-C, . . . where C indicates a continued behavior). The end of an interval was recorded with a specific bar code. The programs automatically prompted

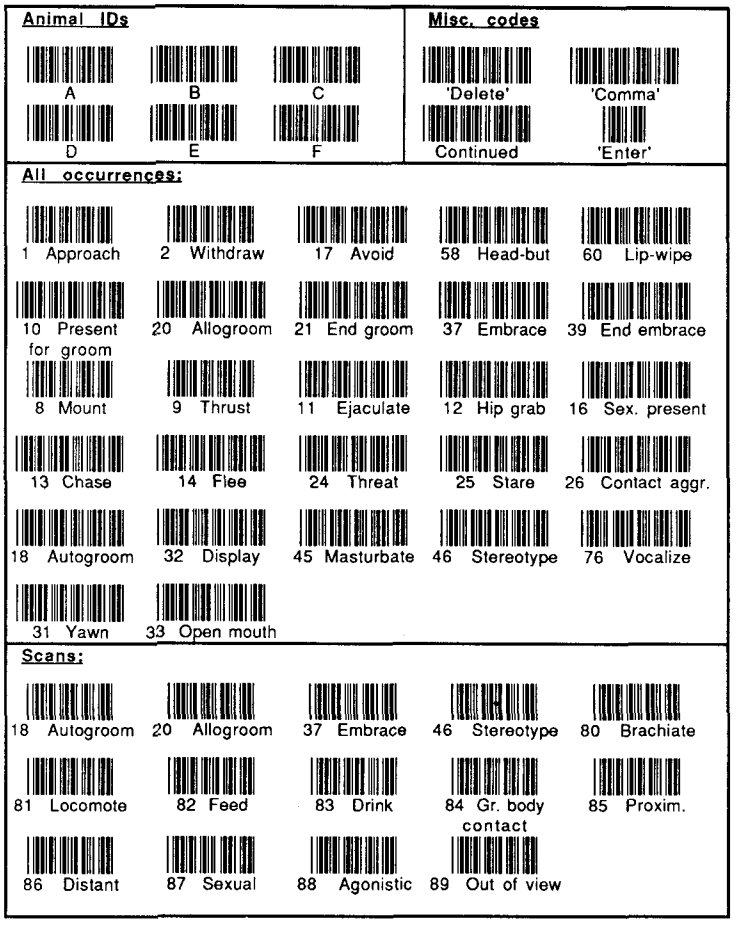

Fig 1. Sample bar code ethogram for the collection of focal animal and group scan data. Animals are identified with a letter code, behaviors have numeric codes.

for scan information when needed, generally at the end of every one or two intervals, as specified when entering header information. The output files contained a header, an interval-by-interval record of behavior sequences, and a table containing scan information. Ad lib notes could be added at the end of the data files.

For the collection of timed focal animal data, the programs were designed to automatically obtain the current time whenever a code was scanned. The start of a new behavior marked the end of the previous one. Individual and cumulative durations were calculated in seconds for all behaviors. The output files contained a header, a table of durations for each behavior, and optionally an interval-by-interval sequence of behaviors.

Focal animal one-zero sampling was simplified with another type of program. After specifying the interval duration and length of the observation period, the observer scanned each behavior as it occurred. The program automatically scored each behavior only once per appropriate interval, and calculated totals for all behaviors. The output files contained a header and the total number of intervals

```
FOCAL          A
DATE           03/31/89
OBSERVER       EWH
LOCATION       EX
WEATHER        1311
DURATION (M)   10
SCAN INT (S)   60
START TIME     08:15:00

SCANS:
A   B
-------
86  86
86  86
20  20
85  85
86  86
87  46
86  46
18  46
86  18
86  86

INTERVALS:
*
A-45-,A-18-,A-21-,B-2-A-,
*

*
B-10-A-,A-1-B-,A-20-B-,
*
CO-,A-21-B-,
*
B-2-A-,
*
A-45-,
*
CO-,
*
A-18-,A-21-,A-18-,
*
CO-,A-21-,A-18-,A-21-,
*

*
<<<END OF OBSERVATION>>>
```

Fig. 2. Sample data file for a combination of focal animal and group scan data. The file is divided into three main sections: header information, scan activity table, and an interval-by-interval record of behaviors for the focal animal. Focal animal data follows the format ACTOR-BEHAVIOR-RECIPIENT. Animals are identified with a letter code, behaviors have numeric codes. Blank intervals indicate that no ethogram behaviors occurred.

during which each behavior occurred. Optionally, it could also print an interval-by-interval table of behaviors that occurred at least once.

RESULTS AND DISCUSSION

Bar code technology enables efficient and accurate data collection, and is adaptable to many research needs. It shares the benefits of other portable com-

TABLE I. Comparison of Efficiency, Accuracy, and Cost of Three Research Methodologies*

	Paper and pencil	Computer with keyboard entry	Computer with bar code entry
Efficiency			
Observer training	Good Memorize behavior codes	Fair Memorize behavior codes learn use of computer	Good Learn use of computer and bar codes
Data processing	Poor Tabulations, data entry	Good Programming, processing	Good Programming, processing
Accuracy			
Timed data	Poor	Good	Good
Correct recording of behavior codes	Fair–Good Observer confuses codes	Fair Observer confuses codes, typographical errors	Good Low probability of confusing codes
Data transcription Quality of errors	Poor Frequent, unpredictable, difficult to detect	Good Some frequent and unpredictable, others rare and systematic	Good Rare, systematic, easy to detect and correct
Cost			
Equipment	Low	Medium-High	Medium-High
Personnel time (for study preparation)	Low Develop forms	Low-High Develop programs	Low-High Develop programs
Personnel time (for data processing)	High	Low	Low

*The three research methodologies include paper-and-pencil, computerized with keyboard entry, and computerized with bar code entry. Criteria used to evaluate the different methods are listed below the rating.

puter systems and offers additional advantages during data collection. For a more complete comparison with traditional paper-and-pencil methods, we discuss advantages and restrictions specific to bar codes and common to all computerized systems. An overview is presented in Table I.

Advantages

Bar codes primarily increase the efficiency of behavioral data collection. A useful feature is the ability to mask the complexity often present in ethograms. Rather than memorizing numerous codes for behaviors, the observer can rely on brief descriptions next to the bar codes, while the computer stores and processes only the code, keeping data concise (Fig. 1). Because of this, overall training time is generally lower than with paper-and-pencil methods, despite the added task of learning to use the bar code system.

Data are entered more accurately because typographical errors are eliminated and observers are less likely to confuse codes when descriptions are readily available next to the bar codes. In addition, bar code sheets can be customized to enable easy location of behavioral codes. For example, behaviors within a general category (i.e., locomotion) can be grouped, and sections can be separated with lines or different background colors. Light colors, such as those obtained with highlighter

TABLE II. Comparison of Complete Processing Time (in Minutes) Required for 1 Hour of Behavioral Data Collected in a Comprehensive Behavior Study*

Manual data collection and processing		Computerized data collection and processing	
Task	Minutes	Task	Minutes
Prepare for observation	5	Prepare for observation	10
Tabulate/summarize data	10–110	Load data files onto storage and analysis computer	5
Check tabulations	10–25		
Organize forms, make copies	5	Edit and backup data files	2–15
Enter into data base	10–75	Check data files, process with program	3–5
		Verify output and transfer to data base, make backups	3–5
Total processing time	40–220	Total processing time	23–40

*The study addressed aspects of social, breeding, play, and feeding behavior, as well as several other behaviors of interest. The ranges reflect differences in processing time for inactive and active sessions.

pens, are recommended to maintain sufficient contrast between light and dark lines within the bar code.

The number of bar codes that fit on a standard 8.5 × 11 inch sheet of paper depends on the layout of the behavior codes and descriptions, but generally should be on the order of 30–60 bar codes when printed at normal size. Reducing the bar codes to approximately 75% with a laser printer not only increases the number of codes a single sheet can hold (up to 90), but it also makes the codes easier to scan. If more bar codes are necessary, the bar code sheet can be set up with a 'keypad' containing only single digit bar codes, from which the complete codes can be created. For example, the observer would scan 2, then 5 to enter the behavior code 25. Less frequently used codes could be entered in this manner from the keypad to reduce the number of codes required on the bar code sheet.

With some practice, scanning bar codes is faster than writing or typing data, so the observer diverts less attention from the study subject while recording information. This is particularly important when studying active animals, such as primates. Accurate durations can be obtained simply by scanning a bar code which immediately records the time. This feature simplifies data collection and also reduces the incidence of missing times. In our study, we scored only mutually exclusive timed behaviors, but overlapping times could be obtained with a slightly different data entry format.

In general, data collected with a computer can be processed more efficiently than with conventional methods, which often require summarizing information before entry into a computer for analysis and storage. Errors in tabulation and transcription are likely to be introduced. In contrast, if the information is already stored in computer files, this process can be performed more quickly and reliably by a computer program. Transcription errors and manual data entry are essentially eliminated. A comparison of time required to process 1 hour of data in a comprehensive behavioral study which began with paper-and-pencil methodology and later utilized the bar code scoring system is described in Table II. For sessions during which the study animals were relatively inactive, computer processing required approximately half as much time as hand-tabulation. As sessions became more active, this advantage quickly increased to more than a five-fold difference in processing time.

The quality of errors also differs for the two methods: with traditional meth-

ods, errors can be introduced during data collection, tabulation, and during entry into a data base for analysis. Such errors are unpredictable and difficult to detect. In comparison, with computerized data collection and analysis, errors are only likely to be introduced while collecting and editing data files. The data tabulation program can include automatic checks for inappropriate information, so these errors may be easily detected. Programming errors could also cause incorrect data tabulation, but such errors are highly systematic and therefore, relatively easy to correct.

A further advantage of computer processing is that, if additional summaries or analyses become necessary at a later time, re-processing computer files requires considerably less time than searching through stacks of data sheets. This is useful in studies where data are collected in more detail than immediately used in analysis, such as when behavioral sequences are obtained, but only frequencies of occurrence or scan data are initially analyzed.

In comparison with the personnel time necessary for manual data processing, a computerized system is also cost-effective. We obtained a complete bar code system using a TRS-80 portable computer for under $600. However, additional funds for development or modification of data entry and processing programs may be required. The amount of time required for this will depend on the complexity of the study, and from our own experience ranges from 2 days to several weeks, with most studies requiring less than 1 week of programming time.

Another key feature is the bar code system's adaptability. From simple to sophisticated data collection requirements, the lap-top computer is easily programmable to meet researchers' needs. After our initial program had been developed for the study of a group of golden monkeys, it was easily modified to meet requirements for studies of other species, including several primates, elephants, cheetahs, and both California and Andean condors. The studies covered a wide range of research interests, including social behavior, chick/juvenile development, feeding patterns, and training responses. As an example, a program developed for the study of cheetah feeding behavior was later modified by a researcher with little previous programming experience for a study of Andean condor chick development.

To facilitate the transition from paper-and-pencil methodology to a computerized system, the programs can be designed to mimic established procedures. Programmable visual and auditory cues allow each data entry program to assist observers and help eliminate common errors. For example, at the end of each required interval, our program buzzed as a reminder to record group scan information, and rejected all inappropriate entries. The format of data files is flexible and easily modified by changing PRINT statements in the program. For rapid analysis, the information can immediately be formatted to meet the specifications of statistical software. If more detail is desired, the data files can be more complex, and a subsequent program can re-format the information for statistical analysis.

Restrictions

We encountered several limitations in using bar codes and portable computers in behavioral research. These problems were minor, and solutions or alternatives were easily implemented, as described below.

When a bar code is successfully scanned, the portable computer emits a beep which acknowledges acceptance of the code. The effect of such tones on the study subject's behavior should be evaluated before using this method of data collection. In our research, some of the study animals were accustomed to noisy environments

and did not seem to react. In other cases, observers collected data from within blinds or at a sufficient distance to avoid influencing the animals' behavior.

If the surface of the bar code is not protected, it quickly frays from contact with the scanning device. A thin plastic cover over the bar code sheet prevents this. In general, thin, non-reflective plastics are recommended, as reflections on the plastic can cause erroneous scans. Minimal pressure should be applied while scanning to prevent the plastic itself from being scratched, as this can also interfere with the scanning of the code. Alternatively, scanning devices are available that do not require contact with the bar code surface.

The lap-top computer requires frequent transfer of data to a larger computer, because it is not suitable for long-term data storage. Its small memory restricts the amount of information it can hold. The internal nickel-cadmium battery allows retention of information for only 8–30 days from the time of the last connection to a power source, depending on the amount of memory installed. However, indefinite file storage is possible by maintaining charged batteries in the computer at all times. If used only for file storage, these batteries need infrequent replacing or recharging. When the computer is operated with battery power, battery life is approximately 14–16 hours. However, the use of the digital wand can reduce operating time roughly by half, depending on the number of codes scanned.

Although the lap-top computer can be programmed to produce auditory signals at specified intervals (e.g., for scan sampling), continuous data entry prevents the use of this feature. The auditory time marker can only be activated before and after input is received, so no signal can be produced while the computer is waiting for an entry. We resolved this problem by setting an external time piece to beep at desired intervals.

Finally, the lap-top computer is susceptible to adverse environmental conditions, such as dirt and moisture. A commercially available, molded plastic cover can be affixed to the computer to protect it without inhibiting keyboard use.

CONCLUSIONS

1. The main advantage of applying bar code technology in behavioral research is the increased efficiency and accuracy of data collection.
2. In particular, studies involving durations can benefit from this technology, because accurate times are easy to obtain. Bar code methodology can also facilitate the application of other common data collection methods, such as one-zero sampling, continuous behavior recording, and focal animal or group scans.
3. More rapid analysis is possible than with traditional paper-and-pencil methodology, since the data files are immediately stored on a computer.
4. Bar codes can make it easier to adopt computerized data collection by eliminating many of the problems associated with keyboard entry.
5. The bar code scoring system provides the flexibility to meet many research needs.

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