COMPUTER TECHNOLOGY

An MS-DOS-compatible data logger for recording subjects' self-ratings

WAYNE H. DENTON

Bowman Gray School of Medicine, Wake Forest University, Winston-Salem, North Carolina

and

NEAL S. WIDMER

Purdue University, West Lafayette, Indiana

Some research designs require subjects to make ratings of their own internal cognitive or affective states or the behavior of other subjects. An ideal device for this purpose should allow for electronic data storage and be easy to use for research subjects. The communication box (Markman & Poltrock, 1982) has been popular for this purpose but consists of dated technology. Other data-logging devices are too complicated for subjects' use. This paper describes an electronic data logger which uses readily available hardware. A dual-tone multiple-frequency (DTMF) telephone keypad encoder is used to generate unique tones that are stored on the audio track of a videotape or on an audio tape. A DTMF receiver decoder IC is used to decode the audio signals. The decoded signals can be read on a light-emitting diode display or entered directly into a personal computer file via an RS-232 serial interface.

In some research paradigms, subjects are required to make ratings of themselves or of other subjects, unlike the more common circumstance in which the investigator rates the behavior of subjects. Examples can be found in marital interaction research. A limitation in the standard approach of having raters code the interaction of marital dyads is that the investigators might impose meaning on the behavior that the subjects do not share. In fact, it has been found that spouses' evaluations of each other's behavior can differ significantly from observers' ratings of the same behavioral sequences (e.g., Floyd & Markman, 1983). Subject self-ratings may also be desirable whenever investigators are interested in subjects' nonobservable internal affective or cognitive states (see, e.g., Markman 1979, 1981).

A key consideration for data entry devices that are to be used by subjects is ease of use. Ease of use is increased by having a simple and straightforward data entry interface with no superfluous buttons or switches. This may require data entry devices designed specifically for use by particular subject populations of interest.¹ In a study on marital communication (Denton, Burleson, & Spre-

kle, in press), we needed a data recording apparatus that could easily be utilized by marital dyads (i.e., had two coordinated data entry devices), would record information on magnetic tape, would be compatible with an MS-DOS personal computer, and would be relatively inexpensive.

A variety of data loggers could conceivably be used by subjects to record self-ratings or ratings of another subject's behavior. Commercial systems, such as the Datamyte (Torgerson, 1977) and the SSR System 7 (Stephenson & Roberts, 1977) are readily available but are designed for use by investigators. Their high level of technical sophistication makes them too complicated for easy use by subjects. Other systems, such as the communication box (Markman & Poltrock, 1982), are specifically designed for use by subjects but their technology is becoming outmoded.

Because we could identify no existing data logging devices that met the needs listed above, we adapted the communication box designed by Markman and Poltrock (1982) for our purpose. In this paper, we describe the resulting electronic data logger, which is assembled from readily available components and which can be employed for subject self-ratings in a variety of situations. We also critique alternative data recording devices and suggest potential applications of the present device.

HARDWARE

The Communication Box

In order to minimize cost, five single-pole push-button switches are used for each box. To record and play back

Preparation of this article was supported in part by awards from the American Association for Marriage and Family Therapy and the Indiana Association for Marriage and Family Therapy. N.S.W. is in the Department of Electrical Engineering Technology at Purdue; requests for reprints should be sent to W. H. Denton, Department of Psychiatry and Behavioral Medicine, Bowman Gray School of Medicine, Wake Forest University, Medical Center Boulevard, Winston-Salem, NC 27157.

10 different possible events (switch closures), a dual-tone multiple frequency (DTMF) telephone keypad encoder (U3) is used (see Figure 1). The tones are recorded on one audio track of a stereo videotape. The sound track of the session is recorded on the second audio channel. A monaural VCR could be used with the audio and DTMF tones being recorded onto the same track. Because automatic gain control can adversely affect the quality of the DTMF tone recordings, a VCR with manual volume control is preferable.

The DTMF encoder, a National Semiconductor TP5088, requires a binary encoded input (see Figure 1). A programmable logic device (PLD) (GAL 16V8) is used to generate the binary code for each unique switch closure. It also provides the logic signal, which indicates when a button is being pressed and assures that only the person who "has the floor" will produce a tone. The logic equations for the PLD are shown below:

$$\begin{aligned} X2 &= !A4 \& !C + !A5 \& !C + !B4 \& C \\ &\quad + !B5 \& C \\ X1 &= !A2 \& !C + !A3 \& !C + !B2 \& C \\ &\quad + !B3 \& C \\ X0 &= !A1 \& !C + !A3 \& !C + !A5 \& !C \\ &\quad + !B1 \& C + !B3 \& C + !B5 \& C \\ P &= !A1 + !A2 + !A3 + !A4 + !A5 + !B1 \\ &\quad + !B2 + !B3 + !B4 + !B5 \end{aligned}$$

Note that the logic operator ! = NOT, & = AND, and + = OR.

Variables A1-A5 and B1-B5 are push buttons on Communication Boxes A and B, respectively. The variable C is generated by a latch circuit that is controlled by a push button on the side of each communication box. These side push buttons are used to surrender the floor.

When any button on the active hand box is pressed, the appropriate binary code is sent to the encoder along with a strobe pulse to enable the tone. Note that the highest order bit in the tone code (D3) represents the subject who is responding. This allows the receiver to distinguish between subjects, if that is desired. An impedance-matching network interfaces the input box with the audio input of the VCR.

The Decoder Box

The decoder box consists of a DTMF receiver decoder IC, the Teltone M-957 (see Figure 2). An inexpensive standard burst frequency crystal for color television is its only external component. It decodes the DTMF signal and produces a 4-bit binary code representing the tone and a strobe pulse which indicates that a tone has been detected. The three least significant bits of the tone code are sent to a seven-segment decoder driver and a light-emitting diode (LED) display, which displays the button number (1-5) as the tone is played back. For manual data collection, no other circuitry is needed than U1, U3, and the seven-segment LED display of Figure 2.

If automated data collection is desired, the RS-232 serial interface circuitry allows for output to a personal computer (Figure 2). Standard components were chosen to

reduce the cost and to minimize complexity. The two 7495 universal shift registers (U6, U7) serve as the parallel-in/serial-out data converter. The data inputs are connected to provide a start bit and three data bits into U7. U6 is set up to generate the higher order bits necessary to form the ASCII code for the tone number being sent. ASCII characters "q,r,s,t,u" are generated for one subject's responses (when D3 = 0), and "1,2,3,4,5" are generated by the other subject's responses (when D3 = 1). On the rising edge of the data strobe from U3, a short-duration (<100 ns) pulse is generated by the circuitry of U2 A and B, latching the mode pins (M) of U6 and U7 to the "parallel load" mode. On the falling edge of the next clock pulse, which is generated by the astable circuit of U5, the parallel data is loaded into the shift registers and the mode line latch is cleared to return it to the "serial shift" mode. The clock circuit of U5 is set to a frequency of 1.2 kHz (1,200 baud). U4 is a TTL to RS-232 level converter which drives pin 3 of the DB-25F serial interface cable. Complete RS-232 protocol is seven data bits, no parity, one stop bit, and 1,200 baud.

The decoder connects directly to a standard RS-232 serial interface connector through pins 3 (Rxd) and 7 (ground). Consequently, it should be operable with any asynchronous RS-232 data terminal device including any personal computer communications port.

SOFTWARE

The software was designed specifically for our application and written in Microsoft's Quick Basic for DOS. Its use in other applications would require some modification of the code. The pseudo code for the software is given below:

- 1 input file name
- 2 open disk file to append
- 3 open com1 port
- 4 ask which column to start with
- 5 get the next character < 6 check if valid
- 7 if not print message, go to 4
- 8 if valid store character, advance to next data slot > 6 check if valid
- 9 continue until F1 is pressed

Figure 3 provides an example of a data file generated with the software designed for our application. It assumes an interaction between husband and wife as described below. ASCII characters "1,2,3,4,5" are produced for the wife's responses, and "q,r,s,t,u" are produced for the husband's responses. The software converts the ASCII letters generated by the husband into the corresponding numbers for the LED display.

The first rating subjects made in our application (Denton et al., in press) was the "intent" rating. To allow either the husband or the wife to initiate the discussion,

Figure 1. Communication box encoder.

Figure 2. Communication box decoder.

Title		DTMF DECODER	
Size	Document Number	REV	
A			
Date:		December 31, 1990	Sheet 2 of 2

Participant	Wife		Husb		Husb		Wife	
Rating	IN	PR	IM	PI	IN	PR	IM	PI
ASCII Char Received	3	5	t	s	u	q	2	3
Rating value shown on monitor	3	5	4	3	5	1	2	3
	+< If Wife initiates discussion start record here.				+< If Husband initiates discussion start record here.			

Figure 3. The data file format (an example of an application, adapted from Denton, Burleson, & Sprenkle, in press). IN, intent; PR, predicted impact; IM, impact; PI, perceived intent. On husband's communication box, ASCII q = a rating of 1, ASCII r = a rating of 2, and so forth.

the software first asks which column to begin with (i.e., the wife "intent" or the husband "intent" column). The eight columns are labeled IN (intent), PR (predicted impact), IM (impact), and PI (perceived intent), for both husband (four columns) and wife (four columns) (adapted from Gottman, Notarius, Markman, Bank, & Yoppi, 1976).

The data are stored on a disk file at the end of the session. Each session for each couple may be stored on a separate file, or all sessions may be appended to the same file. The resulting data file can be used as input data to a statistics package such as SAS or SPSS to evaluate the data through relative frequency analyses, sequential analyses, etc.

COMMUNICATION BOX PROCEDURE

When used with dyads (adapted from Gottman et al., 1976), a "control box" with two red lights (indicating which subject has the floor) is placed between the two subjects. The subject on whose side the red light is illuminated always has the floor to speak. In addition to the red light on the control box, a small light directly on the communication box of the subject controlling the floor also is illuminated to indicate he/she has the floor to speak.

The floor is "passed" to the other subject when a push button on the side of the communication box is pressed. The communication boxes are connected by cables to the control box. Each cable is 5'-6' long, so that the subjects can sit away from the control box and face each other at a comfortable distance.

Once a subject has passed the floor, he/she cannot obtain it again until the other subject passes it back. If a subject presses the rating button on his/her communication box when he/she does not have the floor, no tone is generated. If this feature is not appropriate for other applications, it can be removed simply through alteration of the equations for the programmable logic device listed above. No changes in the circuitry are needed.

Finally, one central green light on the control box is illuminated whenever a subject presses one of the five rat-

ing buttons on the communication box. This merely indicates to the experimenter that the subject has depressed one of the rating buttons.

In the typical dyadic interaction paradigm (adapted from Gottman et al., 1976), subjects who have just spoken can be asked to rate how they intend the other subject to feel about their message and/or how they predict the other subject will actually feel about the message. The listening subjects can rate how they feel about what the other has just said and/or how he/she guesses the other actually wanted him/her to feel.

The software operates under the assumption that the subjects are following the correct protocol in entering their responses. Proper training of subjects in the use of the boxes through an instructional videotape and practice is critical. The subjects were also provided with a cue sheet during our investigation (Denton et al., in press), to remind them of the meaning and sequence of the ratings. After training, subjects must understand the meaning of the ratings they are to make; which rating to make and when to make it; that they cannot change a rating once it has been made; and that they need to depress the rating button for at least a second to ensure that an adequate tone is generated for decoding.

Subjects are to make exactly four ratings for each turn of conversation: two before, and two after speaking. If they make either more or less than four ratings (e.g., if subjects do not depress the rating button long enough to generate a signal, if they forget to make a rating, or if they change their minds and make two entries for one rating), then, during decoding, the computer will receive a husband response code (ASCII codes q-u) during entry into a wife column or a wife response code (ASCII codes 1-5) during entry into a husband column. An error message ("Error, please pause the tape") is generated to avoid data contamination.

The only one of these three potential errors that we actually encountered occurred when subjects sometimes would not depress a rating button long enough to generate a tone that could be read by the decoder. This was probably because in our training we emphasized the other two potential errors but not this one, which we did not anticipate. Examination of the videotape made it possible to determine exactly which rating the subject had not executed properly. The software asks which column to restart data acquisition in, so data loss was limited to one data point.

It is possible that if a subject does forget to make a rating or makes two button pushes for one rating, then, in viewing the tape, the investigator may not be able to detect exactly which of the two ratings is missing or incorrect. In this situation, two data points would have to be sacrificed.

The making of more or less than four ratings per turn of speech will always be detected by this software. Since ratings are made in pairs clearly demarcated by periods of talking, data loss should be limited to one or two data points per subject error. Multiple turns of speech occur

during the discussion period, which helps minimize the impact of any such data loss.

COMPARISON WITH EXISTING DATA LOGGERS

Commercially available data recorders include the Data-myte (Torgerson, 1977) and the SSR System 7 (Stephenson & Roberts, 1977). These electronically sophisticated systems can be adapted to a wide variety of research situations. This also means that their data entry interfaces are relatively complex and may include buttons or switches that are not used in a particular application.

This complexity presents relatively little problem when the devices are used by the investigator, since coders can be given extensive training and practice to ensure accurate use of the device. When a data recording device is used by subjects, however, the time for training and practice is limited. In addition, if subjects have limited familiarity with the use of electronic devices, mastering the use of a complex piece of equipment may be difficult.

Another drawback of having complicated data entry interfaces for subjects is that the procedure becomes more intrusive and may lower the validity and reliability of the data being collected. Since the goal is to have the subjects' ratings reflect their internal states, it is desirable to minimize the number of steps between the internal experience and the physical pressing of a data entry button. The longer the subject pauses in deciding which button to push, the more likely it is that unwanted editing of the inner experience will occur. We have addressed these problems in designing our apparatus by including only five simple push-button switches on the data entry face (as in Markman & Poltrock, 1982).

A technical limitation of the commercial systems is that they do not record the signals directly onto magnetic recording tape as the presently described system does. There may be situations (see, e.g., Floyd & Markman, 1983; Notarius, Benson, Sloane, Vanzetti, & Hornyak, 1989) in which an investigator wishes to compare the "subjective" ratings of subjects with the "objective" ratings of observers. Such a comparison of an "insider's" and an "outsider's" perspective can provide rich insights into the relationship of cognition/affect and behavior. Having the subjects' self-ratings on the same tape as that on which the observers later code facilitates such comparisons. Alternatively, the investigator may wish to compare the subject's self-rating with the content of what was happening in the environmental context (e.g., a subject's reaction to a political speech). Having the subject's ratings and the environmental context on the same videotape facilitates comparisons.

A final disadvantage of the commercial systems is that they are relatively expensive (about \$3,500 for the Data-myte 862 vs. \$175 in materials for the present apparatus).

Other types of data loggers have been developed that do code digital signals onto videotape. The VIDEOLOGGER (Krauss, Morrel-Samuels, & Hochberg, 1988) codes

multiple events occurring simultaneously on a segment of videotape. This system could not be used in settings in which the subjects are to rate their own behavior, since it can only analyze previously recorded videotape and does not allow for real-time recording. Also, the ability to code multiple events occurring simultaneously is unneeded when subjects make only one rating at a time.

Barnes, Haith, and Roberts (1988) developed a system that does allow for the simultaneous recording of digital and video information. The digital information is recorded on the video channel. They cite as an advantage of their system that the audio channel stays free for other uses. However, the use of stereo recording tape permits one audio track to be used for coding digital information (as in the system described here) while the remaining track can be utilized for recording subjects' voices. Barnes et al. cite as another advantage of their system that it can analyze codes every $\frac{1}{10}$ sec, and the codes can still be read when the tape is used in stop image or slow motion. Such precision is unnecessary in research in which the behavior being coded occurs over the course of several seconds or longer (e.g., interactional research).

Drawbacks of Barnes et al.'s (1988) system include that it uses the Apple IIe (rather than the now more common MS-DOS-compatible personal computers), it requires the construction of new circuitry for both the encoding and decoding systems, and the investigator does not have the option of viewing the digital information manually. In addition, the authors apparently used a video-game controller as their input device, which would allow for the recording of only a limited amount of digital information. They do not describe how other input devices might be applied. Although any 8-bit TTL code can be input to the encoder, the authors do not describe the specific circuitry used to interface the joysticks. Any other input device would need to be wired to output a TTL code word of 8 bits or less.

An improvement upon Barnes et al.'s (1988) system was the DataVision device (Ergener & Wellens, 1989). DataVision allowed for the input of more data and could be decoded manually or electronically. Weaknesses of DataVision include that it is relatively expensive, it also uses the Apple IIe computer, it cannot be easily used by subjects, and it "requires several customized chips and an experienced engineer for constructing and testing the digital circuits" (Ergener & Wellens, 1989, p. 405) of the decoder.

The Observer (Noldus, 1991) is a software package for event recording and simple data analysis. A menu-driven set of options provides considerable flexibility in configuring it for specific applications. One of its primary drawbacks for use in subject self-rating is that it utilizes a computer keyboard as the data entry device. This has the disadvantage described above of being overly complex for use by subjects, with the risk of lowering both the validity and reliability of the rating process.

Gottman et al. (1976) developed the "talk table" for marital dyads to utilize in making self- and partner ratings during discussion. An analogous device, the "com-

munication box," described by Markman and Poltrock (1982), was easy to hold in the hand, and it had five buttons on its face so that subjects were not distracted by unnecessary buttons.

In Markman and Poltrock's (1982) communication box system, each of the five buttons selected a timing component and established the output frequency of an astable multivibrator circuit. The output frequency of each box was connected to the left and right audio input channels of a stereo tape deck and recorded on audio tape. Potential disadvantages of this system include: the inability to coordinate audio data with videotape, potential ambiguities between switch data and other audio signals, the inability to disable spouse response when the other spouse is controlling the floor, the inability to manually decipher data without a computer, and the use of the PDP-11/10 mini-mainframe computer (as opposed to the now more common MS-DOS-based personal computer). These limitations were specifically addressed in the adaptation of Markman and Poltrock's communication box described above.

APPLICATIONS

The communication box has been utilized primarily to evaluate communication within marital dyads. Message impact ratings have been found to successfully discriminate distressed from nondistressed married couples (Baccus, 1987; Floyd & Markman, 1983; Gottman et al., 1976; Schachter & O'Leary, 1985). Premarital couples who had negative message impact ratings were more likely to be divorced 2½ and 5 years later than premarital couples with positive message impact ratings (Markman, 1979, 1981).

There are many other potential applications of the communication box (with appropriate changes in the software). Because it is easy to use, the device described here would be practical in a variety of experimental settings in which subjects are to rate themselves or others. In the present configuration it could be used in the study of communication by any pair of subjects, such as dating partners, friends, or strangers. For example, it has been used to evaluate communication between physicians and their patients (Sher, Cell, & Leslie, 1992). It seems simple enough to be used by older children in the study of communication between friends, siblings, parents and children, children and teachers, and so forth.

With individual subjects, only one of the communication boxes could be used. It would be especially adaptable to research situations in which subjects were asked to make responses on a 5-point Likert-type scale and in which it was desirable to pair the subject's rating with video/audio recording. For example, subjects' reactions to a television program (speeches, commercials, children's programming, etc.) could be recorded on videotape with the program also in view, so that it could be determined what types of program content corresponded to particular reactions in the subjects. Pollsters have used touch-tone

telephones to have subjects record their reactions to live political speeches or debates. The present system allows researchers to use the same touch-tone telephone technology on a smaller scale. The present hardware would allow only 1 subject to make ratings at a time.

The boxes could be used by observers to record their own subjective reactions while watching a videotape of subjects' interactions (e.g., Floyd & Markman, 1983; Notarius et al., 1989). Alternatively, observers could use the boxes as standard data loggers with any coding system that has five or fewer codes. (The use of the telephone keypad encoder allows up to 10 different ratings. To conveniently use both boxes simultaneously, the "floor switch" mechanism would need to be disabled by altering the equations listed above for the PLD.) This could be done in a wide variety of settings, as in the observation of children, animals, natural events, and so forth.

Several alternative ways in which this communication box could be utilized would require no modifications in hardware from the present design. It could be used in the field with portable audio or videotape recorders. If an investigator was not interested in the video/audio information, the system could be connected directly to a portable computer and the data stored immediately in a file. Likewise, for an investigator who did not have access to a personal computer, the digital information could be manually decoded with the use of the decoding box, and the data could be transferred to a mainframe computer for analysis.

A device designed for ease of use and low expense does have its limitations. For example, in the present configuration, only 5 different ratings are possible with each box (or 10 with the changes described above). This system could not be used if more than 10 ratings were necessary. The system described here would also not be suitable if precision in timing or other time information was needed. It requires approximately 0.5-1.0 sec of continuous tone before the decoder can decode the signal.

SUMMARY

The communication box system described above is intended to (1) be relatively inexpensive and easy to construct, (2) be uncomplicated for subjects to use, (3) allow the recording of digital information on video/audio tape, (4) give the option of decoding either manually or electronically, and (5) be compatible with any computer that has a serial interface and supports Quick Basic.

Software has been developed utilizing the popular BASIC programming language, which can be used as provided or adapted for the individualized needs of particular studies. The software can be used with the widely available MS-DOS-based personal computers. The relatively low cost and the ease of construction should make this version of the communication box readily available to those investigating subject self-reports in a wide variety of settings and to investigators in need of a relatively inexpensive data logger.

Availability. A copy of the software, with instructions, can be obtained without charge by sending a formatted disk (3.5 or 5.25 in.) to the first author.

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NOTE

1. As an example, for subjects who were children with physical handicaps, one of the authors (N.S.W.) adapted a computer keyboard by dividing it into color-coded regions. Striking any key in a given region would produce a specific rating that was unique to that region (Widmer, 1989).

(Manuscript received October 27, 1992;
revision accepted for publication September 14, 1993.)