An application of interactive voice response (IVR) technology to longitudinal studies of daily behavior

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A relatively new technology—an interactive voice response (IVR) system—was used to collect self-report data from 51 male subjects (21–56 years old) concerning daily tobacco and alcohol consumption over a 112-day period. After resolution of initial technical problems, the Touch-Tone data-entry methodology of the IVR was shown to provide notable advantages over traditional longitudinal self-report methodologies. The high compliance rate (93%) for this study was attributed to (1) implementation of important study design characteristics; (2) an innovative compensation scheme that reinforced consistent daily reporting and incorporated feedback to the subjects on a daily basis; (3) a simple, unobtrusive Touch-Tone data-entry interface with the interview and data-collection system that provided subjects with flexibility and time efficiency; and (4) direct coupling of the automated data-collection system and a relational database-management structure, providing immediate access and analysis of collected data.

Many aspects of everyday health-related behaviors are critically important for personal well-being, public health, and safety in such areas as nutrition, exercise, smoking, and drinking. Maintenance of daily routines that proactively promote mental and physical well-being are universally supported by health professionals for their preventive efficiency and cost-effectiveness. How well particular routines are integrated into different lifestyles and the impact of periodic noncompliance with health routines advocated by professionals are of substantial interest to health-care providers developing preventive-medicine programs. Until recently, however, it has been impractical to collect data regarding the day-to-day behaviors of a large number of subjects over a significant period of time.

This paper describes the interactive voice response (IVR), a newly emerging telecommunication technology, as applied to a relatively large sample (51 subjects) over an extended time (16 weeks). Use of this technology with longitudinal studies can provide detailed, day-to-day behavioral data, collection of which would have been inconceivable only a few years ago. Accurate measurement of self-reported health behaviors such as alcohol consumption and tobacco use have implications for public safety, public health, and clinical efficacy (e.g., treatment compliance), as well as intrinsic scientific interest (Litten & Allen, 1992). While the primary focus of the study described below was daily alcohol consumption, extrapolation of this methodological advance to other health-related

behaviors should be readily apparent. This paper discusses the methodological benefits, practical considerations, and implementation of an IVR system for collection of longitudinal data on a daily basis. Results of the analyzed IVR responses will be published in a scientific journal appropriate to the content (Searles, Perrine, & Mundt, 1995).

Previously obtained data pertaining to longitudinal changes in health-related behaviors, such as alcohol consumption, have been generated by two types of studies. First are large epidemiological surveys conducted at two or more different times which allow broad statements about patterns to be made (Knupfer, 1989) and general trends in consumption patterns to be ascertained (Clark & Hilton, 1991; Wilsnack, Klassen, Schur, & Wilsnack, 1991). However, fine-grained analyses of individual changes over time are not possible with these types of studies. The second source of longitudinal data consists of long-term follow-up studies of clinical samples (e.g., Moos, Finney, & Cronkite, 1990; Polich, Armor, & Braiker, 1981), typically focusing upon treatment efficacy. Attempts to collect frequent data have been successful, but have been conducted for relatively short periods of time, using burdensome, daily written logs or some variant thereof (Dunn, Seilhamer, Jacob, & Whalen, 1992; Lemmens, Knibbe, & Tan, 1988; Seilhamer, Jacob, & Dunn, 1993; Tucker, Vuchinich, Harris, Gavornik, & Rudd, 1991; Williams, Aitken, & Malin, 1985). These studies have reported 90%–100% compliance rates for subjects completing the protocols monitoring daily alcohol consumption for periods of up to 90 days. These daily diary studies have typically used highly selected clinical samples and often have obtained parallel, collateral data regarding the targeted subjects' daily drinking, factors that could easily influence both the representativeness of the

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obtained data and the motivation to maintain a high rate of reporting compliance. The presumed difficulty in obtaining subject compliance in completing daily written reports, as well as the logistic and statistical complexities of managing, analyzing, and maintaining the anticipated volume of paper-based data, are the most likely reasons that more extensive longitudinal studies of daily behaviors are not found in the extant literature.

The longest continuous measurement of daily drinking we have found in the literature, prior to the present study, has been 90 days (Tucker et al., 1991); this study established that carefully instituted procedures can produce high compliance rates. Tucker et al. suggested these procedures should include: "(1) extensive participant training, (2) regular contact with participants throughout data collection, (3) limiting reports to well-defined, observable events that minimized subjective inferences, (4) prospective daily recording to minimize forgetting and (5) assurances of confidentiality and minimization of negative consequences for reported drinking" (p. 153). We added two features of our own to encourage participation: (1) a reinforcement system that maximized reward for daily contact, but did not have severe adverse monetary consequences for an occasional missed day; and (2) the intrinsic interest generated by an automated reporting system that minimized subject effort but ensured high-quality data.

An initial pilot study with 15 subjects reporting over a 21-day period assessed the feasibility of using telecommunications technologies to have subjects self-report daily alcohol consumption, using a voice-mail protocol (Searles, Perrine, & Mundt, 1994). The acceptance of the reporting method by the subjects (99.4% compliance rate) indicated that this methodology was superior to previous methodologies (i.e., written logs) used to obtain longitudinal daily drinking data. The primary difficulties experienced during the feasibility study centered on: (1) the cumbersome nature of the reporting method, which required study participants to repeat a specific script verbally each day; and (2) data management that required transcription of daily verbal reports and hand entry into the database for further processing.

Computer technologies for interfacing with telecommunications equipment have advanced rapidly in recent years, permeating both public and private institutions. These Touch-Tone interfaces provide the means for individuals to interact directly with automated data-collection programs, eliminating a fundamental bottleneck of all previous data-collection techniques, and they are the basis of the IVR system described below.

METHOD

Subjects

Fifty-five men who had participated previously in other studies at the Vermont Alcohol Research Center (VARC) were invited to participate in this project. The sample was representative of the general drinking population of Vermont: 98% white; median age = 28 years (range = 21–56 years); 65% never married, 33% married, 2% divorced; median schooling = 16 years (range = 12–17 years); and

88% employed. Four subjects were dropped from the study due to noncompliance in reporting during the first week. The noncompliance may have reflected frustration with the reporting system that resulted from unavoidable technical problems encountered at the outset of the study. Numerous attempts to contact and re-engage these four subjects after resolution of the problems were unsuccessful.

Apparatus

The 80386-based IVR system is configured as a two-station Lantastic (Artisoft, Tucson, AZ) network designed to process four telephone calls simultaneously. Three incoming lines were dedicated to the interviewing and data-collection system, and the fourth line was dedicated to handling "line-busy" conditions as described below.

The file server administered the interviews, which were controlled by an application program written in EASE (Expert Systems Inc., Atlanta, GA) and implemented by Digital Speech Inc. (Richardson, TX). EASE is one of several IVR application generator programs commercially available, several of which are reviewed by Warren (1994). Data inputs were captured using serial communications boards supplied by Digital Speech and stored by EASE in FoxPro 2.5 (Microsoft, Bethel, WA) database tables. The associated workstation performed daily maintenance of the interview data and acted as a gateway to a second local area network where the data were backed up and analyzed further. Data processing for maintenance of the database and summary reports was performed with FoxPro 2.5.

The telephone system consisted of a user toll-free (800) number managing a four-line hunt group that selected the first available line in the group for incoming calls. The fourth line, selected when the first three lines were busy, was connected to an answering-machine announcement that notified users that all the lines were busy and requested they try again in a few minutes.

Procedure

Each subject called the dedicated 800 number to provide: daily reports of alcohol and tobacco consumption; self-ratings of resulting intoxication; occurrences of drinking and driving; alcohol-related problems; locations of drinking (or reasons for not drinking); and ratings of general mood, stress, and physical health over the 16-week study period. The subjects were asked to respond to a series of short questions (e.g., "How many beers did you drink yesterday?") by pushing the appropriate numbers on the keypad of a Touch-Tone telephone. They were required to call the IVR system once each day between midnight and midnight to report data regarding the *prior* 24-h period (i.e., to report their daily behaviors between midnight and midnight on the day prior to the calling day). Those subjects who did not possess a Touch-Tone telephone were loaned inexpensive devices to allow data entry into the system during the study period. Each subject was assigned a unique identification number and password, both of which were required to access the IVR system. Any subject for whom a daily report existed in the database for the 24-h reporting period at the time of the incoming call was so informed and disconnected from the system. After a subject's response to the last interview question, the completed data record was stored in a FoxPro data file and each subject was informed of the compensation accumulated in his "account" at that time by a synthesized voice (see description of compensation scheme below). Incomplete report records (i.e., disconnection before responses to all of the interview questions were obtained) were not stored in the database. To minimize a potential bias in favor of reporting not drinking on a given day in order to complete a call more quickly, the subjects were required to respond to the same number of questions regardless of whether alcohol had been consumed the previous day. The data entered by the subjects were electronically encoded automatically and associated with an individual account identifiable by the subject's ID and a date/time stamp for storage, analysis, and evaluation. An overview of the system/subject interface is shown in Figure 1.

Figure 1. Interface between the respondent reporting daily behaviors and the IVR interview system. After subject identification and password verification, alcohol consumption questions lead to an interview branch for more specific information about the respondent's drinking or information about why he abstained. After providing alcohol consumption data, the respondents provide tobacco consumption data and information regarding their general psychological and physical well-being. Feedback regarding accumulated cash and bonus-point totals provides positive reinforcement for consistent daily reporting.

The data-collection and -analysis system was custom designed both to minimize the intrusiveness and effort required of the subjects in reporting daily and to maximize subject compliance, data integrity, and ease of data access for study-management purposes. To maintain legibility while graphically representing the IVR system interface with the subjects, the specific wording of each question is not provided in Figure 1 (it is, however, available in Searles et al., 1995), but the question set shown includes the complete content of

the automated interview. Each question required a specific numeric input from the subject, such as the number of drinks or cigarettes consumed, a rating between 1 and 10, or a dichotomously coded response of "1" if true or "2" if false for questions concerning drinking locations or abstinence reasons. Each question began with a keyword relating to the question content (e.g., *Beer*), after which responses were permitted immediately, eliminating the need for practiced subjects to listen to each question in its entirety. Thus, new

subjects were afforded the opportunity to become familiar with the system, question order, and permissible responses in their entirety, while experienced subjects could enter data quickly and efficiently. While the system normally proceeded to the next question automatically after a 2-sec pause following a response, pressing the pound (#) key after a response allowed subjects to advance immediately to the next question of the interview for greater efficiency. If a subject inadvertently entered incorrect data (i.e., pressed the wrong button), a press of the star (*) key allowed the response to the previous question to be re-entered. The subjects were required to provide a response to each question before the IVR system would advance to the next item; thus, multiple drinking locations (or reasons for not drinking) were obtained where relevant. An important feature of the automated data-collection system concerns the elimination of data-transcription errors inherent in all previous paper-based methods of obtaining daily behavioral reports.

Since the primary goal of this type of research is to gather daily data, a compensation scheme that encouraged consistent compliance without excessively punishing occasional violations (thereby discouraging continued efforts at daily reporting) was highly desirable. In the present study, a subject's account was credited 50 cents for each day on which he provided a complete daily report. In addition, bonus points that had potential cash value of \$1 per point at the end of the study were awarded for reporting consistency. For example, subjects were awarded 10 bonus points for reporting on all 7 days of a calendar week (1 point per day plus 3 additional points for a "perfect" week). If subjects missed a reporting day, however, all of their bonus points for that particular week were forfeited. If the subject missed no more than 2 nonconsecutive days during a 4-week (28-day) period, 7 points were restored for those weeks containing the missing data, but the 3 additional points (for a perfect week) could not be recovered. This provided an incentive to continue reporting during weeks in which a day was "missed" while also encouraging daily compliance with a 3-bonus-point premium for perfect calling weeks. At the end of each 4-week period, the subjects were paid the cash balance that had accumulated in their account up to that time. Additionally, half of the bonus points that had accumulated at the midpoint of the study were converted to cash (\$1 per point), and the remainder were left to accumulate with bonus points during the second half of the study; these were converted to cash at the end of the study. These procedures provided regular reinforcement for consistent participation and a strong incentive to continue participating up to the end of the 112-day period.

The daily data, which were collected directly in a FoxPro file format, required approximately 5 min each day to be transferred into an aggregate FoxPro database that accumulated the complete database, thus minimizing data-collection down-time. Subjects calling during this time received a brief message informing them that all incoming lines were busy and asking them to call back shortly. The transferred data were analyzed for subject compliance, and those individuals who had not provided daily reports for 2 consecutive days were identified on a daily basis. These subjects were telephoned by a research assistant to ascertain any reporting problems, obtain the data from the missed days, and encourage continued participation.

The subjects participating in the daily reporting study were initially brought to VARC for a 90-min orientation meeting, during which time the purpose and importance of the study were explained. The reporting procedures and compensation scheme were discussed fully and the subjects were provided with a complete manual for reference. Strategies for keeping track of daily data to allow accurate reporting, originally developed by subjects who had participated in the initial telephone-reporting feasibility study (Perrine, Searles, Mundt, Arce-Quinones, 1995), were also discussed. In addition, the subjects were provided with a laminated, wallet-sized reference card with the toll-free IVR telephone number and the interview questions. This card also contained a telephone number to a dedicated telephone answering machine that could be used to report verbally responses to the interview questions (as implemented during the feasibility study),

should the IVR system malfunction or a Touch-Tone telephone be unavailable for an extended time. At the end of the study, the subjects were brought back to VARC for debriefing using focus-group techniques.

RESULTS

Over the entire 112-day study period, 5,151 daily self-reports were obtained. Unfortunately, several hardware and software difficulties were experienced during the initial two weeks of the IVR system implementation, which prevented 213 daily reports from being obtained during this time. However, using a combination of sporadic IVR system operation, verbal reports to the back-up answering machine, and personal interaction with the research staff, 501 daily reports were obtained during this period. Because the failure to obtain data during this period was due to factors other than subject noncompliance, subject-compliance rates were computed on the basis of data collected during the final 98 days of the study period. Over these 98 days of uninterrupted IVR system operation, 93% of the possible 4,998 daily reports (51 subjects $\times$ 14 weeks $\times$ 7 days/week) were obtained. Of the 4,650 daily self-reports obtained during the final 98 days of data collection, 95.8% (4,455) were on time and self-initiated by the subjects. The remaining 4.2% required a follow-up telephone call by the research assistant. The pattern of daily data reporting also provided some evidence of deterioration in reporting compliance over time. During each week of the 16-week period, 357 reports were possible. Table 1 shows the number of daily reports received each week by the IVR system, the number of late reports obtained by a research assistant, and the number of missing daily reports. It can be seen that, after the technical problems experienced during the first 2 weeks were resolved, self-initiated daily reporting remained fairly constant at 88%–94% over the following 12 weeks, with a drop to about 83% during the final 2 weeks of the study.

The IVR system automatically stored the time (eastern standard time) that each daily report began, and a software upgrade 54 days into the study period also allowed length-of-call information to be collected. These data afford the opportunity to evaluate subject reporting behaviors, as well as the telephone-line load during the final 58 days of the study, which allowed sample-size capacity with different telephone-line configurations to be estimated. Figure 2 shows the percentage of daily reports received by the IVR system as a function of time of day; it can be seen that most of the IVR calls were received in the morning. During weekdays, the number of reports received rose rapidly from 5:00 a.m. until 7:00 a.m., peaked between 7:00 and 8:00 a.m., with almost 12% of the total reports taking place during that hour, diminished until about 1:00 p.m., and then remained fairly constant until after midnight. Weekend reporting demonstrated a similar reporting pattern, with approximately a 2-h offset in the morning rise of incoming reports, a less pronounced reporting peak between 9:00 and 10:00 a.m., and a more gradual decline throughout the later morning and afternoon.

Table 1
Number of Daily Drinking Reports (IVR), Verbal Reports (Late), and Missed Reports (Missed)
as a Function of the Number of Weeks Into the Study

Type of Report	Week															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
IVR	145	295	319	332	337	321	336	324	318	321	314	314	311	314	293	300
Late	50	11	35	18	10	14	7	17	11	15	11	14	10	4	16	13
Missed	162	51	3	7	10	22	14	16	28	21	32	28	36	39	48	44

Note—Daily drinking reports were received through on-time self-initiated use of the IVR system; verbal reports were obtained by a research assistant after the targeted reporting day.

Measurement of each report's duration was not possible until the software upgrade was implemented, although the onset time of each report to the IVR system was available throughout the study period. If each interview question was listened to in its entirety before a response was entered, as would be expected at the beginning of the study, a complete daily report required approximately 2 min and 30 sec (i.e., 150 sec) to enter, assuming no delays or errors during response input. Over the last 58 days of the 112-day study, the average report length was 106 sec (range = 38–286 sec; median = 106 sec), indicating that the subjects made use of the time-saving features that allowed response input immediately following keyword prompts at the beginning of each query. The software upgrade also permitted assessment of the telephone-line load placed upon the IVR system during the final two months of the study. Somewhat surprisingly, only 171 (6.8%) of the 2,541 reports received during this period coincided temporally with another incoming report, and 7 of these overlapped with 2 other simultaneous reports. An analysis of line-idle times that preceded daily reports during the final 58 days indicated that the system was waiting for each report an average of about 33 min. The distribution of idle times was heavily skewed toward longer waiting periods, however, such that the median wait time was 18 min, 31 sec (range = 1 sec–7 h, 49 min, 18 sec).

Figure 2. Percentage of on-time IVR daily reports received on weekdays and weekends as a function of time (eastern standard time). Weekday reporting peaked between 7:00 and 8:00 a.m., while weekend reporting peaked between 9:00 and 10:00 a.m.

DISCUSSION

Touch-Tone data entry is one of the "new and emerging" technologies identified by the Computer-Assisted Survey Information Collection (CASIC) Committee for Technology Transfer of the Census Bureau (Appel & Nicholls, 1994). The present study is, to our knowledge, the first attempt to apply this technology to long-term longitudinal tracking of daily reports of health-related behaviors. This study included more subjects over a longer continuous period than any reported studies of daily drinking behavior of which we are aware. The favorable acceptance of reporting health behaviors on a daily basis using the quick, nonintrusive IVR system is largely responsible for the high compliance rates obtained. This aspect may be the strongest testimony for such technology as a significant methodological advance.

The question set shown in Figure 1 is deceptively simple in that it appears, at first glance, to be a cursory survey of relatively circumscribed daily behaviors of limited informational value. Questions probing particular aspects of daily experience related to drinking behaviors such as marital discord, incidents of physical altercations, and occurrences of particular DSM symptomatology are easily envisioned and were considered for the reported study. It was felt, however, that implementation of such questions would likely provide diminishing returns. The success of collecting these types of longitudinal data is directly connected to the ease and unobtrusiveness of the reporting procedures.

A limited set of questions that remain constant throughout the study period affords the opportunity for the reporting procedures to become innocuous and easily incorporated into the reporting individuals' daily routine, as evidenced by the data reported. Questions probing maladaptive behaviors or the occurrence of relatively rare events (among the general, nonclinical population) would communicate a pejorative attitude toward the subjects, would rarely evoke a positive response, and would raise the need for greater depth to the interview on the rare occasions that the instances did obtain. Longer, more personal, or interactive implementation of questionnaire items would decrease the likelihood that subjects would be willing to participate in the study, and would likely lead to procrastination of their daily report until some anticipated "quiet" time, that might not occur on a given day. The likelihood of not reporting on a given day might even be a function of exactly the behaviors sought by the particular research.

In this type of research, the breadth of the longitudinal study, as a continuous daily time series, is more precious and informative than the depth of the data recorded at any specific point along the series. Major life events such as job loss, familial discord, disputes with law-enforcement agencies, and so forth are matters of public record and are easily recalled retrospectively with clarity, due to their personal poignancy. "Typical" daily behaviors and experiences, however, may fade from memory rather quickly unless recorded soon after their occurrence, and possible relationships between these behaviors and experiences and more memorable events may not be realized. The opportunity to investigate potential relationships between these major life events and development of detrimental daily habits that may not be readily apparent to the individuals engaged in them represents the exciting potential for this type of research.

The ability to obtain these data quickly and inoffensively, without disrupting the behaviors under study or drawing inordinate attention to possible consequences, has shown that a rich, comprehensive data set can be obtained and managed efficiently. A number of other study features made possible by the technology should also be recognized for their role in maintaining subject involvement over the extended four-month period.

First, the compensation scheme was devised specifically to encourage and reward consistent daily reporting; moreover, the penalties imposed for a missed daily report were not so severe as to create a disincentive to continue reporting following an occasional lapse. In fact, the potential reinstatement of bonus points for a missed day—if a consistent reporting record was maintained throughout the surrounding 4-week period—provided motivation to reestablish active reporting status as soon as possible following a missed reporting day. The ability of the IVR system to provide subjects with immediate feedback regarding their accumulated compensation and bonus-point totals at the conclusion of each daily report afforded specific reinforcement to maintain their reporting regimen.

Second, the flexibility of the system allowed the subjects to integrate the reporting requirements into their normal daily routines with minimal effort, as evidenced by the strong diurnal time-of-day reporting patterns shown in Figure 2. Thus, the process of calling in each day at approximately the same time became an established behavioral pattern for the subjects. This pattern became so well established, in fact, that several subjects actually persisted in calling the IVR system for several days after the study was completed!

Third, providing the subjects with a toll-free 800 number permitted them to report their health behaviors even while traveling (or, in one case, after relocating to another state). During the 112-day course of the study, approximately 150 reports were received from outside the local area code, from CA, CT, FL, IL, IN, MA, ME, MI, MN, NC, NH, NJ, NY, OR, PA, RI, TX, VA, WY, and Washington, DC. This aspect of the implemented technology becomes increasingly important for longitudinal studies as the length of study period increases.

Finally, the automated data-collection and management system permitted remedial actions to be taken quickly to secure data that might otherwise have been lost using more traditional reporting methods. Subjects who did not report to the IVR system for 2 consecutive days were contacted by a research assistant to assess potential problems and/or to re-enlist the subjects' active participation. This procedure was extremely effective in recovering data that might otherwise have been lost. Of 256 reports obtained after the targeted date, over 50% (129) were recovered with only a 2-day lapse and 94% (241) were retrieved in fewer than 7 days. With more traditional reporting methods such as written logs mailed weekly—or even daily—much longer lags for data recovery would be expected, if, indeed, recovery of the data were even possible. Thus, the implemented method provides more rapid data acquisition with greater accuracy due to minimal recollection problems. The integrity of the data is also enhanced by circumventing the potential for subjects to procrastinate preparation of the written records until a mail-in deadline or to prepare the records in advance so that they can be mailed on schedule.

The volume and complexity of such data require a sophisticated and well-organized data-management system, such as that provided by commercially available relational database systems (e.g., FoxPro). These systems allow efficient data flow with thorough error checking, eliminating the need for double data entry to reduce transcription errors of written records. Immediate access to transmitted data allows daily generation of summarized reports of expected, received, and missing subject reports and permits appropriate action to be taken in a timely fashion. Compensation earned and bonus-point calculations were performed directly within FoxPro, such that the IVR database was updated daily with the new information, thus providing accurate reinforcing feedback to the subjects.

Even with the high compliance rate obtained from these subjects over the study period, some deterioration in reporting compliance over time was evident, particularly during the last 2 weeks. The obtained data are not adequate to assess whether this reflects a temporal boundary condition for high compliance rates of daily reports, or whether it is simply an end-of-the-study relaxation on the part of the subjects. These data would support the suggestion made by Tucker et al. (1991) that periodic contact be maintained with subjects participating in such reporting protocols. Further, these data would suggest that the time between such personal contacts should not exceed a period of 3–4 months.

This study clearly demonstrates that extended, longitudinal studies with large samples reporting behaviors on a daily basis are practical with the use of newly emerging Touch-Tone data-entry technology. The ability of such studies to obtain the participant acceptance necessary for high compliance and valid data is influenced by the flexibility, speed, and simplicity of the data-collection system, as well as by the reinforcement scheme integrated into the study to encourage participation. These factors are, in turn, dependent on the successful integration of the

data-collection technology with a sophisticated data-management system that allows direct and immediate access to the data obtained on a daily basis.

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