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Audio-CASI

Hardware and Software Considerations in Adding Sound to a Computer-Assisted Interviewing System

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This article reviews a multimedia application in the area of survey measurement research: adding audio capabilities to a computer-assisted interviewing system. Hardware and software issues are discussed, and potential hardware devices that operate from DOS platforms are reviewed. Three types of hardware devices are considered: PCMCIA devices, parallel port attachments, and laptops with built-in sound.

Keywords: survey measurement, survey technology, computer-assisted interviewing (CAI), audio computer-assisted self-interviewing (audio-CASI)

A recent advance in survey technology, audio, computer-assisted, self-interviewing (audio-CASI), provides a potentially important opportunity for improving the validity and reliability of survey measurements used in research on sexual behaviors, drug use, and other sensitive topics. Because survey measurements provide some of the most important information on behaviors related to the transmission of HIV and other STDs, drug use, and other important health and social phenomena, improvements in the accuracy of such measurements could have important benefits for both research and policy making (Miller, Turner, & Moses, 1990, chap. 6).

The principal feature of the audio-CASI approach to survey measurement is that respondents listen to digitally recorded versions of questions and answer choices through headphones, and they enter their answers directly into a computer. Audio-CASI technology thus allows surveys to be conducted in a condition that affords complete privacy to respondents while eliminating the requirement of respondent literacy demanded by other self-administered interviewing procedures, such as paper-and-pencil, self-administered questionnaires (O'Reilly, Hubbard, Lessler, Biemer, & Turner, 1994; Turner, Lessler, & Gfroerer, 1992, pp. 303-305).

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This new technology offers a number of other important methodological advantages (see Turner, Danella, & Rogers, 1995, pp. 187-188). Most importantly,

It can be used with any respondent who can hear; it does not require reading literacy in any language;
It permits efficient multilingual administration of surveys without requiring multilingual survey interviewers (see Hendershot, Rogers, Thornberry, Miller, & Turner, in press; Turner, Rogers, Hendershot, Miller, & Thornberry, 1995);
It offers the traditional advantages of computer-assisted survey technologies (i.e., computer-controlled branching through complex questionnaires, automated consistency and range checking, automatic production of data files, etc.);
It provides a completely standardized measurement system; every respondent (in a given language) hears the same question asked in *exactly the same way*.

Although audio-CASI technology is a relatively recent innovation in survey measurement, there have already been several promising empirical reports of its benefits, particularly in encouraging more complete reporting of sensitive or stigmatized behaviors. Preliminary data from the 1995 National Survey of Adolescent Males, for example, indicate a fourfold increase in the percentage of adolescent males reporting some history of male-male sexual contacts when interviewed using audio-CASI (Turner, Danella, et al., 1995). Similarly, significant increases in the proportion of American women reporting abortions have been observed in pretesting for the 1995 National Survey of Family Growth (Duffer, Lessler, & Mosher, in press).

In this article, we report on our recent experiences adapting hardware and software for audio-CASI applications. We believe our experiences may be of value to others working in this area. The hardware required for adding audio to laptop IBM PC computers is relatively new and evolving rapidly. Indeed, identifying how to interface appropriate software and hardware devices proved to be a significant part of the task of implementing an audio-CASI system. In the present article, we describe what we learned during this process for the potential benefit of readers who are either involved in or contemplate the development of audio-CASI systems for data collection.

DEVELOPMENT OF NEW SURVEY TECHNOLOGY

In 1991, scientists at the Research Triangle Institute (RTI) developed a fully functioning audio-CASI system (O'Reilly, Hubbard, Lessler, & Biemer, 1992; O'Reilly & Turner, 1992; Turner et al., 1992, pp. 304-305). Development of this technology was prompted by an initial discussion of the feasibility of audio-CASI interviewing between the second author and David Celentano of Johns Hopkins University at the February 28, 1991 meeting of the Steering Committee for Project Light—an NIMH multisite evaluation of HIV prevention programs (Project Light, 1991; Turner, 1991). James O'Reilly and Darren DeLoach developed and programmed RTI's first audio-CASI systems.

Work on RTI's initial audio-CASI system was begun in early 1991, and a full working prototype system was produced in the fall of 1991. This technology was successfully pilot tested at RTI during the spring of 1992. Respondents in the pilot test had little difficulty using this new technology, and they reported preferring audio-CASI and video-CASI interviews to paper-and-pencil questionnaires (O'Reilly et al., 1994). Development of similar audio-CASI systems using Apple Macintosh computers was also under way during this period at the University of Michigan (Johnston, 1992) and the University of Maryland School of Medicine (see Stanton et al., 1994).

The minimum configuration for RTI's initial audio-CASI system was a 16Mhz, 286 processor with 1 Mbyte RAM, a 60 Mbyte hard disk, and a VGA monochrome display (see

O'Reilly et al., 1994, pp. 201-202). In developing this system, a laptop MS-DOS system was chosen as the hardware platform because of the greater availability of computer-assisted interviewing (CAI) software for MS-DOS machines, and the growing availability of portable audio-digital devices for MS-DOS (and its successor) operating systems. The key hardware components of the initial RTI audio-CASI system were (a) a laptop PC, and (b) a digital audio device interfacing with the PC through the parallel port. Subsequent systems have been developed for laptop PCs that include built-in Sound Blaster compatible audio devices.

The video display and data management software for RTI's initial audio-CASI technology employed the BLAISE system developed by Statistics Netherlands (1989). The audio hardware component consisted of an external digital audio processor (the ANTEX audioport) developed by ANTEX Electronics. The hardware and software for this system interfaces across the parallel port of the laptop computer. The ANTEX device obtains power through a cable that is connected to the laptop PC's external keyboard port. Integration of the hardware and software audio-CASI components was achieved using an RTI-developed driver that leaves the basic operation of BLAISE intact with a few minor exceptions.

This system is being successfully employed in two major ongoing national surveys—the 1995 National Survey of Family Growth (NSFG) (Duffer et al., in press) and the 1995 National Survey of Adolescent Males (NSAM) (Turner, Danella, et al., 1995). Audio-CASI interviews have currently been completed with over 10,000 women aged 15-44 in the NSFG and with over 1,200 young men aged 15-19 in the NSAM. The audio-CASI part of these surveys has, in general, performed effectively. The audio quality is good, and we have found the ANTEX automatic file compression system to be more efficient than other commonly used compression methods (e.g., Microsoft WAV and Sound Blaster VOC formats). Minor delays in sound playback inherent in these initial audio-CASI applications has proved to be of little practical consequence. Despite the relatively large (5.5" × 8.5" × 2.5") ANTEX audio device and nonstandard power connectors, survey interviewers have adapted to this equipment configuration. Also the respondent to the NSFG survey reported a broad acceptance of the audio-CASI technology (see Kinsey et al., 1995).

Although this audio-CASI technology has proved usable and reliable in our ongoing, large-scale surveys, we have continued to explore ways to improve our implementation of audio-CASI. New developments in hardware have offered the (unproven) potential of implementing audio-CASI on a wider and more convenient range of hardware. These included devices that connected to the parallel port (like the ANTEX device) with improved power source connectors and portability, sound cards that use a Personal Computer Memory Card International Association (PCMCIA) slot, and laptops with built-in audio devices.

New software components were also available. These included packages that provided sound editing and mixing of WAV and VOC formatted files (e.g., VEDIT2). We have also explored, with considerable success, the feasibility of constructing alternative audio-CASI software platforms by adding sound to computer-assisted interviewing packages other than BLAISE. Two pilot studies have been successfully mounted using a new audio-CASI system built on RTI's automated forms system (RTIFS; Cooley, 1994). The RTIFS software platform was modified by the first author so that audio was integrated directly with the video features. This integration was done in the RTIFS source code obviating the need for specialized Terminate and Stay Resident (TSR) routines, such as those used by our initial BLAISE-based system to pass output to the ANTEX audio device driver. This same technique was used by the first author to develop a telephone audio-CASI system (T-ACASI), which was used during the spring of 1995 to field a T-ACASI version of the National AIDS Behavior Survey (see Turner, Miller, et al., 1995).

In the following pages we describe the methods we used to test a variety of hardware devices in our efforts to develop more robust, functional, and convenient implementations of audio-CASI.

METHOD

A review of the hardware available for the laptop computer environment established three categories of sound devices as potential audio sources for our audio-CASI applications: PCMCIA cards, parallel port devices, and laptops with built-in sound hardware. We found that the playfile routines included with the devices we tested were inappropriate for field application because the keystroke used to break out from these playfile programs was not saved. Thus that initial keystroke could not be used as data during the interview. This feature was part of our initial ANTEX- and BLAISE-based audio-CASI system, and it was regarded by RTI's survey specialists as an essential system requirement. (Requiring subjects to waste a keystroke before *every* answer would, they believed, run a great risk of both frustrating our research subjects and introducing keying errors into our research data.)

Accordingly, we developed our own playfile program on a PC workstation using a sound card developer toolkit and a standard PC sound card. Two sound cards were investigated: a Creative Labs Sound Blaster 16 and a Media Vision's Pro Audio 16 (the latter was operated in Sound Blaster compatible mode). Three different toolkits were also investigated. The toolkits are described in three manuals: *Pro Audio Spectrum Developer's Toolkit Reference Manual*, the *Developer Kit for Sound Blaster Series: User's Guide*, and *Ruckus: The Sound Card Toolkit for DOS Compilers*. The playfile programs we developed satisfied all of our requirements for an audio-CASI application, and each of the three playfile routines ran successfully on a PC workstation with one or both types of sound cards. However, only one of them, the Ruckus-based playfile, operated on all PCs (desktop or laptop) equipped with Sound Blaster compatible audio devices. We thus imposed the requirement that any audio-CASI hardware we considered must be Sound Blaster compatible (i.e., our Ruckus-based playfile program must execute properly on that hardware).

Three PCMCIA cards, five parallel port devices, and three laptop computers with built-in sound devices (an IBM 750 Thinkpad computer, a Texas Instruments TM4000M, and IBM Thinkpad 755CSE) were acquired and tested. The demonstration programs included with the devices were run to test sound quality, and we then tested the Sound Blaster compatibility of each audio device. Table 1 presents the list of devices included in our review. This table lists the device, the manufacturer, and the price, along with the device type and the weight.

It should be noted that this list is not intended to be exhaustive. A review of PCMCIA devices ("Multimedia Direct," 1994) and a review of portable multimedia hardware (Stone, 1994) was used to identify the items included in Table 1. The three computers were identified through various review articles, including a recent review of laptop personal computers (Howard, 1994).

RESULTS

All of the devices provided acceptable sound quality when the test software (i.e., the playfile code included with each device's demonstration package) was used to play standard WAV or VOC files. Table 2 presents the results of our testing. It should be emphasized that the qualitative comparison of the devices with respect to overall sound quality was made from the perspective of *voice* playback quality. Eight bit sound files recorded at a sampling rate of 8,000 Hz provides acceptable sound quality for the audio-CASI application. Hence the quality assessment was based on subjective clarity and loudness criteria. All of the devices

TABLE 1
List of Sound Devices

Device	*Manufacturer*	*Approximate Price*	*Type*	*Weight*
Antex AudioPort	Antex Electronics	$389	Parallel	1 lb., 7 oz.
Port-Able Sound Plus	DSP Solutions, Inc.	$198	Parallel	1 lb., 13 oz.
Sound Exchange Model B	Interactive	$229	Parallel	2 lb., 6 oz.
Audioman	Logitech, Inc.	$179	Parallel	13 oz.
Audioport	Video Associates Lab, Inc.	$295	Parallel	13 oz.
The Cat	Vocal Tec.	$179	Parallel	10 oz.
IBM PCMCIA 16 Bit Audio Adapter	IBM Corporation	$265	PCMCIA	4 oz.
Tempe Audio Card	IO Magic Corporation	$299	PCMCIA	4 oz.
WAVJammer	New Media Corporation	$399	PCMCIA	3 oz.
Thinkpad 750	IBM Corporation	$4,700	Built-in	NA
Thinkpad 755CSE	IBM Corporation	$4,099	Built-in	NA
TM4000M	Texas Instruments	$3,900	Built-in	NA

NOTE: Prices shown reflect those prevailing at time of purchase (for single-unit retail sales). Prices for most devices have declined since 1994-1995; this is particularly true for laptop PCs with built-in sound devices.

produced acceptable sound quality, primarily because high sound quality is not a critical requirement of the audio-CASI application. On the other hand, the Port-Able Sound Plus device produced very clear and loud sound quality. The IBM PCMCIA card and the WAVJammer card also produced sound that was clear and of good quality. (We did not repeat these experiments with different headphones, etc., and we readily acknowledge that the sound quality ratings are highly subjective. We emphasize that all of the tested devices are capable of meeting the audio-CASI standard for sound quality.)

Our second goal was to identify appropriate devices that satisfied our Sound Blaster compatibility criteria. Table 2 presents the results of our testing. This testing uses our definition of Sound Blaster compatibility for the purposes of audio-CASI development. Specifically, a device was judged to be Sound Blaster compatible if it would play WAV/VOC files in DOS using the playfile routine developed with the Ruckus toolkit. The playfile routine developed with RUCKUS operated on workstations with both sound cards and on all three Sound Blaster emulated systems (i.e., the Port-Able Sound plus, the TP755CSE, and the TM4000M devices).

Nine of the 12 sound systems were not Sound Blaster compatible under DOS and, consequently, they would not play the same WAV/VOC files using the Ruckus-based playfile program. It is of interest to note that many of the systems that failed our Sound Blaster compatibility test in DOS operate successfully in Windows 3.1. As Table 2 indicates, none of the PCMCIA cards was Sound Blaster compatible in DOS. This reflects a basic conflict between PCMCIA standards and Sound Blaster design standards. Sound Blaster requires use of a direct memory access (DMA) channel for interfacing the sound device with the CPU. PCMCIA standards explicitly do not allow the use of DMA channels. One parallel port device proved to be Sound Blaster compatible, and it produced high-quality sound as good or better than all of the others tested. That device—the Port-Able Sound Plus—is thus fully capable of supporting our audio-CASI field applications.

The category of laptop PCs with built-in audio devices was initially disappointing because our initial experiments in 1994 with the IBM Thinkpad 750 indicated that the audio device

TABLE 2
Tests of Sound Devices for Audio-CASI Applications

Device	*Sound Quality*[a]	*Sound Blaster Compatible*[b]
Parallel port devices		
Antex Audioport	Acceptable	No
Port-Able Sound Plus	Excellent	Yes
Sound Exchange Model B	Acceptable	No
AudioMan	Acceptable	No
Video Associates Audioport	Acceptable	No
The Cat	Acceptable	No
PCMCIA cards		
IBM PCMCIA 16 Bit Audio Adapter	Excellent	No
Tempe Audio Card	Acceptable	No
WAVJammer	Excellent	No
Laptop PCs with built-in audio		
Thinkpad 750	Acceptable	No
Thinkpad 755CSE	Acceptable	Yes
TM4000M	Acceptable	Yes

a. Subjective assessment of voice quality sound; does not assess music quality.
b. Ability to play WAV/VOC files using Ruckus-based playfile routine operating under DOS operating system.

used in this laptop was not Sound Blaster compatible. We thus had to use a separate (parallel port type) device to implement audio-CASI applications on this machine (we ultimately used a Port-Able Sound Plus device). However, experiments with the TM4000M indicated that it satisfied our Sound Blaster compatibility criteria with acceptable sound and speed attributes. Subsequent to our acquisition of the TM4000M, a number of other laptops with built-in sound have been advertised by a variety of manufacturers. These include the IBM Thinkpad 755CSE—a successor to the IBM Thinkpad 750. We tested the IBM Thinkpad 755CSE in 1995, and we found it to be Sound Blaster compatible and to provide acceptable sound quality for audio-CASI.

DISCUSSION

We have reviewed available technology for incorporating digitally recorded sound in audio-CASI applications. In addition to the audio hardware mentioned above, a set of software tools were used to develop a playfile program that provided the functionality we required. Three versions of this program were developed using software purchased from three different sources, each supporting a Sound Blaster protocol. In addition to the requirement of support for the Sound Blaster protocol, we restricted our review to DOS-based systems. However, we plan eventually to move our audio-CASI applications to both Windows and OS/2 platforms. The requirement of support for the Sound Blaster protocol should not restrict moves to either of these operating systems.

Audio-CASI has provided the potential for obtaining sensitive information that is more accurate than information obtained using other means or technologies (Duffer et al., in press; Turner, Ku, Sonnenstein, & Pleck, in press; Turner, Miller, et al., 1995). Currently, it is possible to use newly available laptop computer technology as the hardware component of an audio-CASI system without the need for any additional sound audio hardware. This technology is only recently available, and prices of laptop computers with built-in audio technology are still falling (we purchased four monochrome Texas Instruments TM4000M laptops for under $1,700 each in 1995).

There are other alternatives providing acceptable sound quality for supporting audio-CASI applications on DOS platforms. These alternatives were reviewed, and while this review was not exhaustive, it identifies two kinds of hardware devices that add sound capabilities to laptop computers: parallel port devices and PCMCIA devices. The latter lack true Sound Blaster compatibility features on a DOS platform, and they were thus not considered by us as appropriate elements of our near-future audio-CASI applications. However, one of the parallel port devices provides acceptable audio-CASI sound quality and is Sound Blaster compatible under DOS. Although this device is bulky and requires a separate (standard nine-volt) power supply, economic considerations favor it as the audio element for an audio-CASI application when sound is added to preexisting laptop computers. We suspect, however, that most future audio-CASI applications will use laptop computers with built-in sound devices operating on a variety of software platforms.

SOFTWARE

BLAISE. Statistics Netherlands, Voorburg, the Netherlands, Netherlands Central Bureau of Statistics.

Developer kit for Sound Blaster series: User's guide. Creative Labs Inc., 1901 McCarthy Boulevard, Milpitas, CA 95035; telephone: 405-742-6622. (Languages supported are Microsoft Assembler version 4.0 or later, Microsoft C version 5.0 or later, Turbo C version 2.0, Microsoft QuickBasic version 4.5, Microsoft Basic Professional Development System version 7.0, and Turbo Pascal 6.0.)

Pro Audio Spectrum Developer's toolkit reference. Media Vision, Inc., 47221 Fremont Boulevard, Fremont, CA 94538; telephone: 510-770-0968. (Languages supported are Microsoft version 6.1 or later, and Microsoft Assembler version 5.1.)

RTIFS-RTI's automated form system. Research Triangle Institute, Box 12194, Research Triangle Park, NC 27709; telephone: 919-541-6000.

RUCKUS: The sound card toolkit for DOS compilers. Cornel Hult, 6402 Ingram Road, San Antonio, TX 78238; e-mail: cornel@crl.com. (Languages supported include Borland C version 3.1 or later, Microsoft C version 5.0 or later, and a number of Basic compilers.)

VEDIT2—Voice editor II. Creative Labs, Inc., 1901 McCarthy Boulevard, Milpitas, CA 95035; telephone: 405-742-6622.

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