The effect of computer-assisted interviewing on data quality. A review.*

Edith D. de Leeuw, Interuniversity Graduate School of Psychometrics and Sociometrics
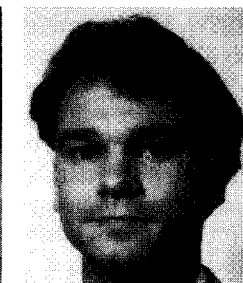**Joop J. Hox**, Department of Education, University of Amsterdam
Ger Snijkers, Statistics Netherlands

E.D. de Leeuw   *J.J. Hox*   *G. Snijkers*

This paper summarises what is currently known about computer-assisted data collection methods (CADAC). The emphasis is on survey data quality and acceptance of the computer by respondents and interviewers. The article starts with a taxonomy of the various computer-assisted data collection methods and a discussion on data quality. This is followed by a review of factors influencing survey data quality. Subsequently for each of the principal CADAC methods in use the empirical research literature is reviewed. The main conclusions are that computer-assisted data collection methods are accepted by both respondents and interviewers, and that survey data quality improves, especially when complex questionnaires are used. It is argued that studies on data quality have been too restricted and that the potential of computer-assisted data collection methods has not been fully utilised.

Introduction
Whether computer-assisted data collection methods should be used in social

research is no longer an issue. Most professional research organisations, commercial, government and academic, are adopting these new methods with enthusiasm. Computer-assisted telephone interviewing (CATI) is most prevalent and computer-assisted personal interviewing (CAPI) is rapidly gaining in popularity. New interesting forms of computerised data collection, for instance automatic speech recognition, are also emerging. This raises the question of the influence of computer-assisted data collection methods on the quality of the data. In this article we review the literature on the topic, focusing mainly on the three basic forms of data collection in surveys: the face-to-face interview, the telephone interview, and the (mail) questionnaire. For a review of electronic observation techniques such as barcode scanning, or automatic registration of TV watching (people- or TV-meter) we refer to Saris (1989). For an interesting discussion on the potentials of people-meters that goes beyond mere registration and into full-fledged media research see Samuels (1994).

We start our review with a taxonomy of different types of computer-assisted interviewing and a discussion of data quality. Next, we present a model of the factors that may lead to differences in data quality between computer-assisted and traditional interview procedures. Subsequently, we give an overview of the results of empirical research on data quality differences. Finally, we discuss the consequences of our findings for social and market research.

Taxonomy of different forms of data collection.
Computer-assisted methods for survey research are often summarised under the global terms CADAC (Computer-Assisted DAta Collection), CASIC (Computer-Assisted Survey Information Collection), and CAI (Computer-Assisted Interviewing)[*]; in this context the traditional paper-and-pen methods are often denoted by PAPI (Paper-And-Pen Interviewing). For a comparative review, see Weeks (1992); reviews that also offer some insight in the usage of computer-assisted methods in European countries are inter al, Hippler & Beckenbach (1992), Hox, De Bie & De Leeuw (1990), and Porst, Schneid & Van Brouwershaven (1994). Characteristic for all forms of computer-assisted interviewing is that questions are read from the computer screen, and that responses are entered directly in the computer, either by an interviewer or by a respondent. An interactive program presents the questions in the proper order, which may be different for different (groups of) respondents. There are three survey modes where CADAC may be employed.

COMPUTER ASSISTED TELEPHONE INTERVIEWING (CATI)
This is the oldest form of computer-assisted interviewing (cf Nicholls & Groves 1986). Originally CATI would be employed centrally using a minicomputer system. Each interviewer sits behind a terminal and asks the questions that appear on the screen; the respondent's answer is then typed into the computer by the interviewer.

* Since the acronym CAI is also used in education for Computer-Assisted Instruction, we prefer to avoid this term.

Supervisors are present for quality control and to assist with specific problems. This is still the most usual CATI setup, with a microcomputer network replacing the minicomputer system. However, the technological change to personal microcomputers means that it also possible to conduct a decentralised CATI survey, for instance from the interviewers' own homes.

COMPUTER-ASSISTED PERSONAL INTERVIEWING (CAPI)
In CAPI, interviewers visit respondents with a portable computer (generally a notebook) and conduct a face-to-face interview using the computer. After the interview the data are sent to a central computer, either electronically by modem or by sending a data disk by mail (cf Baker 1992; Saris 1991).

COMPUTER-ASSISTED SELF INTERVIEWING (CASI)
This method is also called Computerised Self-Administered Questionnaires (CSAQ) or Prepared Data Entry (PDE). Characteristic for CASI is that the respondents themselves read the questions on the screen and enter the answers. There is no interviewer; the interviewing program guides the respondent through the questionnaire.

CASI can appear as part of a CAPI session where the interviewer hands over the computer to the respondent for a short period, but remains available for instructions and assistance. This is equivalent to the procedure used in traditional PAPI face-to-face interviews where an interviewer might give the respondent a paper questionnaire containing sensitive questions.

Two different computer-assisted equivalents of the mail survey are the Disk-By-Mail (DBM) and the Electronic Mail Survey (EMS). In DBM a disk containing the interviewing program is sent to the respondent, who runs the program on his or her own computer and then returns the disk with the responses (cf Higgins, Dimnik & Greenwood 1987). It is obvious that at present this works only with special populations, who have access to a computer. These may be private persons, but also corporations. Within corporations particularly this method is used to collect inventory data for recurring stock-taking (cf Weeks 1992). DBM has also been used in surveys of teachers, using the school's computer (cf De Leeuw 1989) and of experienced PC-users (Jacobs 1993).[*]

In EMS the survey is sent by electronic mail through existing computer networks, electronic mailing systems, and bulletin boards. Users of such systems receive a request to participate in a survey, and if they comply, they either are asked a number of questions by an interviewing program, or they receive an electronic form to fill in at a later stage. This is currently only possible with special populations, but the limited experience so far is positive (cf Kiesler & Sproull 1986).

A fourth form of CASI is the tele-interview (Saris 1991). This is a form of computer-assisted panel research (CAPAR) where respondents fill in an electronic

* The DBM survey of Jacobs was a survey of experienced PC-users on the amount of illegally copied software they owned. Thus, DBM was not only practical with this population, but also profitable because it ensured complete privacy.

questionnaire about once a week.* For this, a large number of selected households receive a microcomputer and a modem. At regular intervals, the modem automatically queries a remote computer, and the computer receives new questionnaires for selected members of the household. After the questionnaires have been answered using the interviewing program, the data are sent back to the remote computer. For questions and technical problems a help desk is available through a toll-free number. The tele-interview has the advantage that it is not confined to special populations with access to computers. However, the tele-interview shares all the methodological problems of traditional panel research (see Kaspzryk, Duncan & Kalton 1989), although experience has shown that the bonus of having a free home computer leads to very low panel loss. The Dutch NIPO research institute has operated a highly successful 'Telepanel' since 1987 (cf Van Doorn 1987; Van Doorn & Hess 1989). The 'Gallupchannel' in Finland is another example (cf Samuels 1994). A variation on the tele-interview is an electronic diary for time budget and consumer behaviour research (Kalfs 1993).

Both Weeks (1992) and Saris (1991) mention two very specific applications of CASI: Touchtone Data Entry (TDE) and Voice Recognition (VR) or Automatic Speech Recognition (ASR). In the first case a respondent is called by a computer, the questions are asked by a computer voice, and the responses are given by punching the appropriate number. In VC the respondent has to answer 'yes' or 'no' verbally. Automatic Speech Recognition has far more potential; in ASR a large vocabulary of meaningful words, such as holiday destinations, can be understood and acted upon by the interview system (Blyth & Piper 1994). For a review and comparison with interviewer techniques, see Havice & Banks (1991).

Table 1
Taxonomy of computer-assisted interviewing methods

Specific method	Computer-assisted form
face-to-face interview	CAPI (Computer-Assisted Personal Interviewing)
telephone interview	CATI (Computer-Assisted Telephone Interviewing)
written questionnare (general self-interview)	CASI (Computer-Assisted Self Interviewing) Synonyms: CSAQ (Computer Self-Administered Questionnaire) and PDE (Prepared Data Entry)
mail survey	DBM (Disk-by-Mail) and EMS (Electronic Mail Survey)
panel research	CAPAR (Computer-Assisted Panel Research), Tele-interview, (Electronic diaries)
various (no interviewer)	TDE (Touchtone Data Entry), VR (Voice Recognition), ASR (Automatic Speech Recognition)

* In CAPAR the tele-interview may be alternated by CAPI or CATI, thus leading to a mixed mode design.

Table 1 presents a systematic overview of the various computer-assisted interviewing methods.

Quality criteria
There can be no dispute that we should aim for high quality data. But what exactly defines high quality? Can there be any absolute standards? Deming, in 1944, stressed that absolute accuracy is a mythical concept and that it is more profitable to speak of tolerance bands or limits of likely error. He further pointed out that allowable limits must vary from case to case, depending on the resources available and the precision needed for a particular use of the data.

A review of the literature on survey error and data quality (Groves 1989) reveals four identifiable sources of error: coverage, non-response, sampling and measurement or response error. The effects of measurement error and to a lesser degree non-response error can far exceed those of sampling error (cf Denny & Galvin 1993) and can be a serious threat for data quality. When studying factual behaviour, it is sometimes possible to estimate the precise accuracy of the data by comparing the survey results with some record or observational data. Usually such data are not available and for research on attitudes, opinions and intentions these criteria for data quality are impossible to use. In those cases other criteria have been used such as item missing data, detail on open questions, and social desirability. Groves (1989) also explicitly incorporates cost considerations into the discussion of survey quality.

When writing a review one is always restricted by the content and the amount of detail in the original articles. Until now, research articles on computer-assisted interviewing have mainly focussed on the acceptability of this new technology and the consequences for response rates and on item-missing data. In a few cases social desirability and detail on open questions have also been investigated. Systematic cost-estimates are rare. Therefore, this review is limited to data quality as indicated by high acceptability, low unit and item non-response and high detail on open questions (completeness) and low social desirability bias. Whenever data were available costs have also been considered.

A model for the influence of CADAC on data quality
Computer-assisted interviewing has rapidly become popular partly because of the expectation that it would lead to better data quality than traditional methods (cf Denny & Galvin 1993). A priori there are three groups of factors that may affect data quality: (1) the technological possibilities of CADAC programs; (2) the visible presence of a computer; and (3) the effect of CADAC on the interviewing situation. The consequences of CADAC for costs will also be addressed.

TECHNOLOGICAL POSSIBILITIES
Compared with an optimally implemented paper-and-pen interview, the optimally implemented computer-assisted interview has five apparent advantages.

(1) There are no routing errors. If a computer system is correctly programmed,

routing errors, that is, errors in the question order, skipping and branching, do not occur. Based on previously given answers the program decides what the next question must be, and so both interviewer and respondent are guided through the questionnaire. Missing data because of routing and skipping errors do not occur. Questions that do not apply to a specific respondent are automatically skipped. As a result, automatic routing reduces the number of data errors.

(2) Data can be checked immediately. An optimally implemented CADAC program will perform some internal validity checks. The simplest checks are range checks, that compare the given response with the range of possible responses. Thus the program will refuse the response '8' to a seven-category Likert scale, and then ask to correct the response. Range checks are straightforward when the question has only a limited number of response categories. More complicated checks analyse the internal consistency of several responses. Consistency checks are more difficult to implement; one must anticipate all valid responses to questions, list possible inconsistencies, and devise a strategy for the program to cope with them. In PAPI, internal validity checks have to be conducted in the data cleaning stage that usually follows the data collection stage. However, when errors are detected, they can only be recoded to a missing data code because it is no longer possible to ask the respondents what they really meant. In a CADAC session there is an opportunity to correct range and consistency errors, and therefore CADAC should lead to fewer data entry errors and missing data.

(3) The computer offers new possibilities for formulating questions. One example is the possibility of randomising the order of questions in a scale, giving each respondent a unique question order. This will eliminate systematic question order effects. Response categories can also be randomised, which avoids question format effects (e.g. recency effects). The computer can also assist in the interactive field-coding of open questions using elaborate coding schemes, which would be unmanageable without a computer. Finally, the computer can be used to employ question formats such as drawing line lengths as in psychophysical scaling, which are awkward to use in PAPI methods.

(4) There is no separate data entry phase. This means that the first tabled results can be available soon after the data collection phase. On the other hand, construction and programming of the questionnaire takes considerable time in CADAC. Thus, a well-planned CADAC survey has a real advantage when the results must be quickly available (as in election forecasts).

(5) The knowledge that the system accurately records information about the interview process itself (e.g. time and duration of the interview, the interval between interviews and the order in which they are carried out) inhibits interviewers from 'cheating'. Computer-assisted interviewing provides a research organisation with greater interviewer control and offers some protection against undesirable interviewer behaviour.

VISIBLE PRESENCE OF THE COMPUTER
The visible presence of a computer may affect the data quality, apart from the technical aspects of using a computer. As with most technological innovations these

effects are temporary. After a time everybody gets used to the new machine, and its influence on the situation is small. Clearly, we are currently in a transition period; the computer is no longer an unimaginable technological wonder, but it is not yet a common household item.

Compared with the traditional PAPI methods, the visible presence of a computer could lead to four effects on the way the respondents or the interviewers perceive the interview situation.

(1) *Less privacy*. When one is totally unfamiliar with computers there could be a 'big brother' effect, leading to more refusals and socially desirable answers to sensitive questions. When researchers first started to use CAPI, there was considerable concern about this effect.

(2) *More privacy*. Using a computer could also lead to expectancy of greater privacy by respondents; responses are typed directly into the computer and cannot be read by anyone who happens to find the questionnaire. In the western world, where computers are widespread and familiar, this reaction is more likely than the 'big brother' reaction.

(3) Trained interviewers may feel more self-confident using a computer, and behave more professionally. This could lead to more confidence of the respondent in the interviewing procedure. Social exchange theory, as applied to the survey process (Dillman 1978) predicts that this should lead to more willingness to comply with the interviewers' requests.

(4) In panel research the availability of a free home computer acts as a reinforcement for the respondents to continue to participate faithfully. Disk-by-Mail (DBM) and electronic mail surveys (EMS) both have a strong novelty effect: the survey request is highly visible, and not likely to be incorrectly perceived as junk mail. This should lead to a higher willingness to participate.

EFFECT OF THE COMPUTER ON THE INTERVIEW SITUATION
The effect of CADAC on the interview process depends strongly on the amount of training and/or experience the interviewers have with this method of data collection.

Inexperienced interviewers may direct much of their attention to keeping the computer running and correctly typing in the answers. If interviewers cannot touch-type, typing in long answers may lead to less eye contact between interviewers and respondents, causing the interviewers to miss nonverbal reactions of the respondents. If the computer is located between the interviewer and the respondent, even the physical distance may be greater than in PAPI. The methodological survey literature stresses the importance of good (nonverbal) communication and rapport between interviewers and respondents. If using the computer weakens the relation between interviewer and respondent, the interview will not be conducted optimally, and in consequence the data quality may suffer.

On the other hand, an experienced interviewer can rely on the computer for routings and complex question sequences, and therefore pay more attention to the respondent and the social processes involved in interviewing. Sometimes, for

instance in asking sensitive questions, less eye contact is an advantage (cf Argyle & Dean 1965); experienced interviewers can use the presence of a computer to their advantage by directing their attention to the screen when asking sensitive questions.

The conclusion is that in a CADAC survey we need interviewers who are well trained and experienced in computer-assisted data collection techniques. This means that in addition to a thorough basic interview training, an additional training in computer usage and computer-assisted interviewing is needed (see Woijcik, Bard & Hunt 1992, for a training program for computer-assisted interviewing). Given well-trained and experienced interviewers, the altered interview situation is likely to have more advantages than disadvantages, especially with sensitive questions.

TIME AND MONEY: CADAC AND ITS CONSEQUENCES FOR COSTS

Going from paper-and-pencil to computer-assisted interviewing requires initial investments, not only in equipment, but also in time. One has to invest in hardware, in software and in acquiring hardware- and software-related knowledge and skills.

As mentioned above, basic interviewer training now needs to include training in handling a computer and using the interview software. But in contrast to this extended general interview training, training for actual surveys is less costly. Many topics (skipping, branching, selection rules) need not be taught because the interview software now handles this (see Porst *et al* 1994). Executives, research directors and field managers also have to learn about, and appreciate, computer-assisted interviewing.

After the initial investments are made a CADAC survey may be cheaper than traditional data collection, but it all depends on the study, its complexity, its size, and its questionnaire. To evaluate the cost efficiency of CADAC a distinction should be made between front-end processing and back-end processing. In general, a well-designed computer-assisted data collection requires investment of more time, effort, and money in the beginning of the research (front-end processing), time that is saved at the end stage (back-end processing). The design and implementation of range and consistency checks (front-end) reduces the time needed for preparation of the data for analysis (back-end); and no questionnaires have to be printed and coded.

In other words developing, implementing and testing the questionnaire is more expensive, but no data entry is needed and data editing and data cleaning cost less. In general, there is no difference in the total time needed for the research. But, once the interviewing has started, results are available much faster than in traditional paper-and-pencil interviewing. Samuels (1994) mentions a reduction of delivery time of 50% for the results of an omnibus survey. When time considerations and fast release of results are important for a client, this is an important advantage of CADAC over paper-and-pencil methods.

In the sections below, we review the results of empirical comparative research on the effects of computer-assisted interviewing versus paper-and-pen methods on data quality, in face-to-face, telephone, and self-administered interviews. Since ac-

ceptance of the computer-assisted methods is an important criterion in itself, we will also include research on the attitudes and opinions of interviewers and respondents. When possible, data on cost comparisons have been added.

Data quality in CAPI

EFFECT ON THE RESPONDENT

Although the first users of CAPI were afraid of a negative effect on response rate, even in the first applications of the method in Sweden and The Netherlands this did not occur (Van Bastelaer, Kerssemakers & Sikkel 1987, p 39). Later studies confirm that CAPI and paper-and-pen methods yield comparable response rates in studies in the USA (Bradburn, Frankel, Baker & Pergamit 1992; Sperry, Bittner & Brandon 1991; Thornberry, Rowe & Biggar 1991), England (Martin, O'Muircheartaigh & Curtice 1993), Sweden (Statistics Sweden 1989) and Germany (Riede & Dorn 1991). These studies also report very low percentages of spontaneous negative reactions by respondents (1-4%). Most reactions are neutral or positive.

When respondents are explicitly asked for a reaction to using the computer they generally react positively. Baker (1990, 1992) reports that most respondents find CAPI interesting and amusing, and attribute a greater degree of professionalism to CAPI. The social interaction with the interviewer is generally described as comfortable and relaxed. Only a small percentage (5%) reports negative feelings. When explicitly asked about data privacy, 47% have more trust in the privacy of computer-collected data, 5% have more trust in traditionally collected data, and 48% see no difference.

Beckenbach (1992) conducted a small scale and well-controlled study comparing CAPI, CSAQ and a paper-and-pen face-to-face interview. After the interview, both interviewers and respondents filled in a questionnaire with questions about the interview itself. Neither interviewers nor respondents report problems with eye contact or social interaction. In the computer-assisted methods (both CAPI and CSAQ) respondents were more positive about data privacy, and judged answering sensitive questions as less unpleasant.

EFFECT ON THE INTERVIEWER

Interviewers are in general markedly positive about computer-assisted interviewing. They appreciate the support that a good CAPI system offers when complex questionnaires are employed (Riede & Dorn 1991; Edwards, Bittner, Sherman Edwards & Sperry 1993), they like working with the computer (Martin *et al* 1993), and derive a feeling of professionalism from it (Edwards *et al* 1993). Riede & Dorn (1991) point out that the one important complaint by interviewers is about the difficulty of grasping the overall structure of the questionnaire. CADAC questionnaires are typically screen-orientated, and it is not always possible to backtrack to earlier sections of the questionnaire for corrections or additions to earlier answers. Advanced CADAC programs have this flexibility, but they still have more constraints than paper-and-pencil methods (Weeks 1992).

The studies in the previous paragraph all employed well-trained and computer-experienced interviewers. This is important, because Van Bastelaer *et al* (1987)

found clear differences between interviewers with and without experience in computer-assisted interviewing. They report that in the first week of data collection the percentage of interviewers that prefers CAPI was 52%, while in the third week this percentage had increased to 71%. An intensive training in using the computer and the specific CADAC program is essential (cf Bennet & Goodger 1993; Woijcik, Bard & Hunt 1992). With good training, older interviewers and interviewers without any previous computer experience can also enjoy using the computer and conduct good interviews (Edwards et al 1993).

At first, interviewers may experience problems with open-ended questions. When they are not keyboard literate and lack typing skills, entering a detailed answer to an open-ended question can be slow and laborious. However, when interviewers gain keyboard experience they become fast enough typists correctly to record answers verbatim (Bond 1991; Denny & Galvin 1993).

The weight of the computer is sometimes mentioned as a problem (Edwards et al 1993). In a study of the ergonomical aspects of microcomputers used in computer-assisted interviewing Couper & Groves (1992) also conclude that weight is an important ergonomic factor. Other ergonomic aspects have also been investigated. Beckenbach (1992) reports that 80% of the interviewers have no problems with screen or keyboard, while 75% report no problem at all. Finally, in the comparative study by Edwards et al (1993) about three in four interviewers report that they found PAPI more tiring!

EFFECT ON DATA QUALITY

The acceptance of computer-assisted face-to-face interviewing is high for both respondents and interviewers, and there are no indications that using a computer disturbs the interviewing situation (Beckenbach 1992). In addition, a well-implemented CAPI system prevents many interviewer mistakes. As a result, we may expect that, compared with traditional paper and pen methods, computer-assisted interviewing has a positive effect on data quality.

Empirical studies tend to confirm this expectation. The percentage of missing data is clearly lower in CAPI, mostly because interviewers cannot make routing errors (Sebestik, Zelon, DeWitt, O'Reilly & McCowan 1988; Olsen 1992). In a pilot CAPI study Bradburn et al (1992) find that the number of missing data caused by respondents ('don't know', 'no answer') also diminishes, but in the main study this is not replicated (Baker & Bradburn 1992; Olsen 1992). Other studies also fail to find a difference in respondent-induced missing data (Bemelmans-Spork, Kerssemakers, Sikkel & Van Sintmaartensdijk 1985; Martin et al 1993).

Little is known about data quality with open questions. Baker (1992) summarises a study by the French national institute for statistical and economical research (INSEE) that does not find any difference between PAPI and CAPI in this respect.

An early comparative study by Waterton (1984; see also Waterton & Duffy 1984) reports a positive effect of CAPI with a sensitive question about alcohol consumption; using the CAPI method more alcohol consumption was reported, which presumably means that CAPI was less affected by social desirability bias. However, in the CAPI mode the sensitive question was asked by letting the respondents type

their own answers into the computer, unseen by the interviewers, which makes this part of the interview more like a self-administered questionnaire. In the PAPI mode the question was asked and the answer taken down by the interviewers. Since self-administered questionnaires typically show less social desirability bias than face-to-face interviews (De Leeuw 1993), the difference between PAPI and CAPI in this study may well correspond to a difference between an interview and a self-administered questionnaire. Other studies that compare PAPI and CAPI more precisely report slightly less social desirability bias with CAPI (Baker & Bradburn 1992; Bradburn et al 1992; Martin et al 1993), but the differences are very small, generally smaller than differences typically found in comparisons of face-to-face versus telephone interviews or experienced versus inexperienced interviewers (Olsen 1992).

EFFECT ON COST EFFICIENCY

There are very limited data on cost comparisons between CAPI and paper-and-pencil personal interviews. Bond (1991) states that even when computers are used frequently in the fieldwork it will take about a year before the investment starts to pay back. Besides frequency of use, sample size is also a key factor for cost efficiency. Only with large sample sizes are the cost savings in printing, despatch, and data entry and editing (back-end costs) greater than the extra costs of questionnaire design and implementation (front-end costs). For example a long interview with closed questions only using a sample of 2000 or more will lead to a savings of 30%, a shorter questionnaire with a couple of open-ended questions and a sample of around 200 will only save around 5% (Bond 1991). In these cost calculations the initial investment in equipment and in special training of staff has been excluded.

Two studies systematically assess costs for CAPI: initial investment in hardware and software was excluded, but extra fieldwork costs for training and supervision were included. Sebestik et al (1988) compared costs in a small scale CAPI experiment (total sample CAPI+PAPI 200). Their conclusion is that overall CAPI was more expensive, mostly because of added costs in training and supervising interviewers. In a larger experiment (around 300 respondents in each condition) Baker & Bradburn (1992) conclude that CAPI was still more expensive (12%) than PAPI; the cost reduction in entering and cleaning data was not large enough to offset the higher training and supervision costs. Baker (1990) extrapolates these findings and concludes that when hardware costs are excluded, approximately 1500 CAPI interviews are needed to reach the break-even point between increased front-end and decreased back-end costs. However, several key cost elements will decline as organisations gain experience in computer-assisted interviewing and hardware costs continue to fall.

Computer-assisted telephone interviewing (CATI)

EFFECT ON THE RESPONDENT

In telephone interviewing the respondent will generally not notice whether a computer is used or not; therefore we may expect little, if any, difference between traditional telephone interviewing and CATI. This is confirmed by comparative studies. Groves & Nicholls (1986) conclude in a review that there are no differences

in non-response, a conclusion also reached in comparative studies by Catlin & Ingram (1988) and Groves & Mathiowetz (1984).

Respondents may occasionally hear keyboard clicks, or be told by the interviewers that a computer is used. No systematic research has been done on the effects of this knowledge, but the general impression is that it makes no difference to respondents if they know that their answers are typed directly into a computer (Catlin & Ingram 1988; Groves & Nicholls 1986; Weeks 1992). This is similar to results found in the comparisons of traditional versus computer-assisted face-to-face interviewing reviewed above.

EFFECT ON THE INTERVIEWER

There is little research on the effect of CATI on the interviewers. Groves & Nicholls (1986) report that interviewers generally have a positive attitude toward CATI. They remark that acceptance of CATI strongly depends on the speed and reliability of the CATI system that is employed.* Weeks (1992) concludes that modern CATI systems are fast and reliable, and that interviewers prefer CATI to paper-and-pen methods. Spaeth (1987) in her survey of survey organisations also reports that staff members in general (both supervisors and interviewers) preferred CATI to PAPI.

Computer-assisted interviewing often leads to greater standardisation of the interview, to the extent that interviewers sometimes complain about 'rigidity' (Riede & Dorn 1991, p 51). In general researchers will appreciate this greater standardisation, because it minimises interviewer bias (Fowler 1991). Furthermore both Spaeth (1987) and Berry & O'Rourke (1988) reported that survey organisations tend to spend more time training interviewers for CATI than for PAPI, and sometimes also employ more supervisory staff. There is some confirmation of greater standardisation of interviewer behaviour in CATI: in a controlled comparative study, using the same interviewers both for traditional and for computer-assisted interviews, Groves & Mathiowetz (1984) found less interviewer variance in CATI than in the paper-and-pen method.

EFFECT ON DATA QUALITY

Although CATI is the first form of computer-assisted interviewing that came into general use, there is little research on the influence of CATI on data quality. In their review Groves & Nicholls (1986) conclude that CATI leads to less missing data because it prevents routing errors, but this effect is only important with complex questionnaires. For the same reason, post hoc data cleaning finds more errors with traditional paper-and-pen methods than with CATI. They find no difference in respondent induced missing data because of 'don't know' and 'no answer' responses.

More recent research by Catlin & Ingram (1988) confirms these conclusions. Catlin & Ingram paid special attention to the possible effects on open questions;

* At the time of their review, CATI systems were running on mainframe or minicomputer systems, and both system speed and reliability were not always optimal for interactive interviewing. Modern microcomputer networks are much better in this respect.

they found no differences in typing errors, codability or length of answer (number of words used). This is similar to results found in CAPI (cf Baker 1992).

EFFECT ON COST EFFICIENCY

Most studies that attempt to weigh the costs and advantages of CATI conclude that the investments pay off only in large scale or regularly repeated surveys. A rule of thumb is that the break-even point is at about thousand interviews. Below that number, the argument of cost reduction is by itself not sufficient to use CATI (cf Weeks 1992).

Computer-assisted self interview (CASI)

Computer-assisted self-administered questionnaires are a relatively new development. CASI differs clearly from both CAPI and CATI by employing a different interviewing situation. The computer has taken the role of the interviewer. Theoretically, this combines the advantages of traditional self-administered questionnaires, such as more openness with sensitive questions, with the possibility of using complex question structures.

A disadvantage of CASI is that at present only selected populations can be studied. Comparative research on CASI has also mostly been done on selected populations, which either had access to computers, or received a computer for the duration of the study.

EFFECT ON RESPONDENT

Respondents generally like CASI; they find it interesting, easy to use, and amusing (Zandan & Frost 1989; Witt & Bernstein 1992). Beckenbach (1992) reports that more than 80% of the respondents had no problem at all using the computer and the interviewing program, and that few respondents complained about physical problems such as eye-strain.

The general positive appreciation of CASI also shows in the relative high response ratio with Disk-By-Mail (DBM) surveys, and in the low panel mortality in the tele-interview. Saris (1989) reports, for a large Dutch panel, a mean response of the active panel members of 98% per week and a panel mortality of 15% per year. (However, the initial non-response for the panel was 50%, cf Kalfs 1993.) DBM response ratios vary between 25% and 70%, and it is not unusual to have response ratios of 40% to 50% without using any reminders (Salzman 1992). Assuming that this is a special population interested in the research topic, an ordinary well-conducted mail survey using no reminders may be expected to yield about 35% response (Dillman 1978; Heberlein & Baumgartner 1978). Of course, one should realise that DBM is restricted to special populations who have access to a personal computer.

EFFECT ON DATA QUALITY

Respondents are generally positive about CASI. We expect that respondents will experience a higher degree of privacy and anonymity, which should lead to less social desirability bias. Beckenbach (1992) reports the two following controlled laboratory experiments that compare traditional self-administered questionnaires

with CASI. In the first, Martin & Nagao (1989) compared CASI with face-to-face interviewing and a traditional self-administered questionnaire; using the Crowne-Marlowe social desirability scale they found less social desirability bias in the self-administered questionnaire, and even less with CASI. In the second, Evan & Miller (1969) compared CASI with a traditional self-administered questionnaire; they found that CASI leads to more openness with questions that are perceived as threatening, and no difference on non-threatening questions.

The same picture emerges in studies of electronic mail questionnaires. Sproull & Kiessler (1991) report five experiments on decision-making in small groups. Using an electronic network for communication leads to more open communication, more ideas, and general participation in the discussion. In the face-to-face situation the discussion tended to be dominated by one or two high-status individuals. This may also be the result of differences in the social interaction. However, in a direct comparison of a mail questionnaire and an electronic mail health questionnaire Kiessler & Sproull (1986) also found fewer socially desirable answers in the electronic version. They also investigated other aspects of data quality in this study. Both the item non-response and the number of errors were lower with CASI. The responses to open questions did not differ, until the edit facilities of the CASI program were improved; then CASI led to longer and more personal answers.

The effect of computerisation on the quality of the data in self-administered questionnaires has also been a concern in psychological testing. The American Psychological Association's *Guidelines for computer-based tests and interpretations* (1986, p 18) explicitly states that '. . . the equivalence of scores from computerized versions should be established and documented before using norms or cutting scores obtained from conventional tests.' The growing popularity of computerised psychological testing has led to several studies that assess the equivalence of conventional psychological tests and their computerised versions. In general, no differences between computer-assisted and paper-and-pencil tests were found in reliability and validity of the tests (Harrel & Lombardo 1984; Parks, Mead & Johnson 1985). One study (Canoune & Leyhe 1985) found that questions involving social pressure (conformity, evaluation) were answered differently in computerised and face-to-face questioning, with the face-to-face version leading to more socially desirable answers and more tension reported by respondents, but other studies (Koson, Kitchen, Kochen & Stodolosky 1970; Rezmovic 1977) did not find this effect. A meta-analysis of 29 studies comparing conventional and computerised cognitive tests (Mead & Drasgow 1993) found that power tests (ability tests without restrictive time limits) were highly equivalent (the cross-mode correlation is .97), but speed tests (cognitive tests measuring cognitive processing speed) were less equivalent (the cross-mode correlation is .72). Mead and Drasgow interpret the mode-effect for speeded tests as an effect of the importance of perceptual and motor skills in responding quickly to such tests.

The general conclusion is that paper-and-pen and computer-assisted psychological tests are highly equivalent. This conclusion is corroborated by a study by Helgeson & Ursic (1989), who conclude from protocol analyses that there are no clear differences in the cognitive processes employed in responding to a traditional

or a computer-assisted psychological test. The differences between the computerised and paper-and-pen tests are the result of differences in motor skills under time pressure and possibly in less inhibition of respondents on highly sensitive topics.

EFFECTS ON COST EFFICIENCY
There are no systematic cost comparisons for CASI. The literature about Disk-by-Mail reports that DBM is generally more expensive than a comparable paper-and-pen mail survey. However, the gain in response in a single mailing is thought to be worth the extra costs (e.g. Wilson 1989).

Discussion
In reviewing the literature about CADAC, a conspicuous feature is that almost all publications start with summing up the potential advantages, such as cost reduction, higher efficiency, and improvement of response rate (cf Snijkers 1992). However, for most of these potential advantages the empirical evidence is still limited.

Most of the research on mode effects investigates the acceptability by respondents and some aspects of data quality. A systematic comparison of costs is difficult (see Groves 1989), and consequently these are rare. When the total costs of paper-and-pen and computer-assisted survey research are compared, the evidence for cost reduction is not very strong (Baker 1990; Catlin & Ingram 1988; Nicholls & Groves 1986). However, once the initial investments in equipment and personel are made, the technical possibilities and the efficiency of computer-assisted techniques of CAI will be preferred by both executives and clients (cf Samuels 1994). Just as CATI is now routine in telephone surveys, CAPI will become the future standard in market research.

There is little evidence that CATI or CAPI improves the response rate. Conversely, there is also no evidence for a decrease in response rate. In panel research (CAPAR) and in Disk-by-Mail surveys (DBM) there are advantages in the form of less panel attrition in CAPAR and better response rates in DBM. However, all relevant studies used selected groups of respondents.

At present, there is still little empirical research into the effect of computerised interviewing on data quality. Instead, most studies have investigated the acceptance of the new techniques by interviewers and respondents. Both interviewers and respondents evaluate computer-assisted interviewing positively. Comparative research has also paid little attention to the effect of computerisation on interviewer variance and on other aspects of interviewer behaviour (an exception is Groves & Mathiowetz 1984).

Computerised methods of data collection generally have a positive effect on data quality. The improvements in data quality are similar for CAPI and CATI, and for CASI the improvements reported point in the same direction. Overall, there are advantages in using the computer with sensitive questions; respondents are less inhibited, but the differences are small. Much of the improvement in data quality is the result of fewer interviewer and respondent errors; a well-designed computerised questionnaire simply does not allow certain types of mistakes. For example,

one general finding is that item non-response decreases because there are no more routing errors.

A strong feature of CADAC is the potential to prevent errors by controlling routing and executing range and consistency checks, but CADAC is not being used to its full potential. The various aspects of data quality that have been studied are too limited. The strength of computer-assisted data collection methods is the ability to increase the power of interviewing and thus be able to answer more complex research questions (Bond 1991). We should explore the potential of the computer and use techniques for data collection that are impossible or impractical without it. An example is the application of computerised diaries in time budget research, which makes it possible to use very fine distinctions (Kalfs 1993). Another possibility is the presentation of graphical stimuli, for instance for magnitude scaling (Saris 1989), and automatic time registration in interviews (Bassili & Fletcher 1991). Bond (1991) gives a detailed description of two measurement techniques that would be almost impossible to use without a computer: Natural grouping and Adaptive Conjoint Analysis. These methods are extremely useful for brand research and positioning of new products.

Another interesting capability of computerised interviewing is extreme tailoring. In this technique different respondents are asked different subsets of the questionnaire. There is a complex routing structure, in which the answers to (combinations of) earlier questions determine the questions that are asked next. This allows for a high degree of structured individualisation of the questionnaire without the subjectivity that comes with an open interview. Kuijlen (1993) has used extreme tailoring in eliciting scenarios that respondents use in purchasing mortgages. A related method is adaptive testing used in psychological measurement. In computerised adaptive testing the computer program selects questions from a pool of possible questions related to the psychological trait to be measured. Based on the responses to questions asked earlier, the program calculates a provisional estimate of the respondent's score, and then selects from the pool of remaining questions that question that maximises the information than can be obtained from the next question. The process ends when all questions have been used, or when the program decides that the respondent's score can be estimated with sufficient precision.

Instead of tailoring the questions to the respondents, respondents can also be tailored to the questions. Poulsen (1993) describes an adaptive CATI system that segments respondents during the interview with a minimum of questions. The resulting segmentation variable is then used in the remainder of the interview for skipping and branching. Thus, different subgroups of respondents receive different questions.

Clearly CADAC is no panacea for good data quality. Computerised data collection methods require one to do almost everything that is needed with a good paper-and-pen interview, and to add extra efforts in computer implementation, in testing the questionnaire, and in extra interviewer training. This investment is earned back in far less interviewer error and the error-free administration of complex questionnaires. We should avoid strong time pressure on both interviewers and respondents: time pressure interacts with the perceptual and motor skills needed for

correct reading of questions and typing in the answer. In addition, research has shown that question texts are harder to read on a monitor than on paper (Mead & Drasgow 1993), which implies that ergonomical text presentation and careful screen design is important for good CADAC surveys. Only if such efforts are made, is there the opportunity for obtaining better data. But, to paraphrase Bond (1991) we have to push further and increase the value of computer interviewing. Computer-assisted data collection has given us beautiful tools to work with. We should use these tools intelligently and devise new ways to measure what respondents can tell us if we only 'listen'.

References

AMERICAN PSYCHOLOGICAL ASSOCIATION (1986). *Guidelines for computer-based tests and interpretations*. Washington, DC: APA.

ARGYLE, M. & DEAN, J. (1965). Eye-contact, distance and affiliation. *Sociometry*, 28, pp 289-304.

BAKER, R. P. (1990). What we know about CAPI: its advantages and disadvantages. Paper presented at the annual meeting of the American Association of Public Opinion Research, Lancaster, Pensylvania.

BAKER, R. P. (1992). New technology in survey research: computer-assisted personal interviewing (CAPI). *Social Science Computer Review*, 10, pp 145-157.

BAKER, R. P. & BRADBURN, N. M. (1992). CAPI: impacts on data quality and survey costs. Information Technology in Survey Research Discussion Paper 10 (also presented at the 1991 Public Health Conference on Records and Statistics).

BASSILI, J. N. & FLETCHER, J. F. (1991). Response time measurement in surveys. *Public Opinion Quarterly*, 55, pp 331-346.

BECKENBACH, A. (1992). *Befragung mit dem Computer, Methode der Zukunft?. Anwendungsmöglichkeiten, Perspektiven und experimentelle Untersuchungen zum Einsatz des Computers bei Selbstbefragung und persönlich-mündlichen Interviews.* [In German: Computer-assisted interviewing. A method of the future? An experimental study of the use of a computer by self-administered questionnaires and face-to-face interviews]. Ph.D. thesis. Universität Mannheim.

BEMELMANS-SPORK, M., KERSSEMAKERS, F., SIKKEL, D. & VAN SINTMAARTENSDIJK, H. (1985). Verslag van het experiment 'het gebruik van draagbare computers bij persoons en gezinsenquêtes. Centraal Bureau voor de Statistiek. [In Dutch: Report of an experiment on the use of portable computers in person and household surveys. Netherlands Central Bureau of Statistics]

BENNET, D. & GOODGER, C. (1993). Interviewer training for CAI at OPCS. Paper presented at the 1993 Conference of the Study Group on Computers in Survey Analysis. City University, London.

BERRY, S. H. & O'ROURKE, D. (1988). Administrative designs for centralized telephone survey centers: implications of the transition to CATI. In R. M. Groves, P. P. Biemer, L. E. Lyberg, J. T. Massey, W. L. Nicholls II & J. Waksberg (Eds.) *Telephone survey methodology*, pp 457-474. New York: Wiley.

BLYTH, W. & PIPER H. (1994). Speech recognition – a new dimension in survey research. *Journal of the Market Research Society*, 36, 3, pp 183-203.

BOND, J. (1991). Increasing the value of computer interviewing. *Proceedings of the ESOMAR Congress*.

BRADBURN, N. M., FRANKEL, M. R., BAKER, R. P. & PERGAMIT, M. R. (1992). A

comparison of CAPI with PAPI in the NLS/Y. Chicago: NORC. Information Technology in Survey Research Discussion Paper 9 (also presented at the 1991 AAPOR Conference, Phoenix, Arizona)

CANOUNE, H. L. & LEYHE, E. W. (1985). Human versus computer interviewing. *Journal of Personality Assessment*, **49**, pp 103-106.

CATLIN, G. & INGRAM, S. (1988). The effects of CATI on costs and data quality: a comparison of CATI and paper methods in centralized interviewing. In R. M. Groves, P. P. Biemer, L. E. Lyberg, J. T. Massey, W. L. Nicholls II & J. Waksberg (Eds.) *Telephone survey methodology*, pp 437-456. New York: Wiley.

COUPER, M. P. & GROVES, R. M. (1992). Interviewer reactions to alternative hardware for computer-assisted personal interviewing. *Journal of Official Statistics*, 8, pp 201-210.

DE LEEUW, E. D. (1989). Computergeleid enquêteren; Een overzicht van technologische vernieuwingen [In Dutch: Computer-assisted data collection. A review of technological changes]. *Tijdschrift voor Onderwijs Research*, 4, 201-213.

De Leeuw, E D (1993). *Data quality in mail, telephone and face-to-face surveys*. Amsterdam: TT-Publikaties.

DENNY, M. & GALVIN, L. (1993). Improved quality at the touch of a button: the use of computers for data collection. *Proceedings of The Market Research Society Conference.*

DILLMAN, D. A. (1978). *Mail and telephone surveys: The Total Design Method.* New York: Wiley.

EDWARDS, B., BITTNER, D., EDWARDS, W. S. & SPERRY, S. (1993). CAPI effects on interviewers: a report from two major surveys. Paper presented at the US Bureau of the Census Annual Research Conference, Washington DC.

EVAN, W. M. & MILLER, J. R. (1969). Differential effect of response bias of computer vs traditional administration of a social science questionnaire: an exploratory methodological experiment. *Behavioral Science*, 14, pp 216-227.

FOWLER, F. J. Jr. (1991). Reducing interviewer-related error through interviewer training, supervision, and other means. In P. P. Biemer, R. M. Groves, L. E. Lyberg, N. A. Mathiowetz & S. Sudman (Eds.) *Measurement errors in surveys*, pp 259-278. New York: Wiley.

GROVES, R. M. (1989). *Survey errors and survey costs.* New York: Wiley.

GROVES, R. M. & MATHIOWETZ, N. A. (1984). Computer-assisted telephone interviewing: effects on interviewers and respondents. *Public Opinion Quarterly*, 48, pp 356-369.

GROVES, R. M. & NICHOLLS, W. L. II (1986). The status of computer-assisted telephone interviewing: Part II – Data quality issues. *Journal of Official Statistics*, 2, pp 117-134.

Havis, M. J. & Banks, M. J. (1991). Live and automated telephone surveys: A comparison of human interviewers and an automated technique. *Journal of the Market Research Society*, 33, 91-102.

HARREL, T. H. & LOMBARDO, T. A. (1984). Validation of an automated 16PF administration procedure. *Journal of Personality Assessment*, 48, pp 216-227.

HEBERLEIN, T. A. & BAUMGARTNER, R. (1978). Factors affecting response rates to mailed questionnaires: a quantitative analysis of the published literature. *American Sociological Review*, 43, pp 447-462.

HELGESON, J. G. & URSIC, M. L. (1989). The decision process equivalency of electronic versus pencil-and-paper data collection methods. *Social Science Computer Review*, 7, 296-310.

HIGGINS, C. A., DIMNIK, T. P. & GREENWOOD, H. P. (1987). The DISKQ survey method. *Journal of the Market Research Society*, 29, pp 437-445.

HIPPLER, H. J. & BECKENBACH, A. (1992). Computer-assisted questioning: developments, restrictions and future possibilities. In F. Faulbaum (Ed.) *Advances in Statistical Software 3; Softstat 1991*, pp 403-410. Stuttgart: Fischer.

HOX, J. J., DE BIE, S. & DE LEEUW, E. D. (1990). Computer-assisted (telephone) interviewing: a review. In J. Gladitz & K. G. Troitzsch (Eds.), *Computer-aided sociological research*. Berlin: Akademie-Verlag.

JACOBS, M. A. (1993). *Software kopen of kopiëren? Een sociaal-wetenschappelijk onderzoek naar pc-gebruikers* [In Dutch: Buying or copying software? A study of PC-users]. Amsterdam: Thesis-publishers.

KALFS, N. (1993). *Hour by hour; effects of the data collection mode in time use research.* Amsterdam: Nimmo.

KASPRZYK, D., DUNCAN, G. J. & KALTON, G. (1989). *Panel surveys*. New York: Wiley.

KIESLER, S. & SPROULL, L. S. (1986). Response effects in electronic surveys. *Public Opinion Quarterly*, 50, pp 402-413.

KOSON, D., KITCHEN, C., KOCHEN, M. & STODOLOSKY, D. (1970). Psychological testing by computer. The effect of response bias. *Educational and Psychological Measurement*, 30, pp 803-810.

KUIJLEN, A. A. A. (1993). De scenario benadering. Een onderzoek naar complexe consumentenbeslissingen met behulp van computergestuurd enquêteren [In Dutch: The scenario method: a study of complex consumer decisions using computer-assisted interviewing] Ph.D. thesis. Katholieke Universiteit Brabant.

MARTIN, C. L. & NAGAO, D. H. (1989). Some effects of computerized interviewing on job applicant responses. *Journal of Applied Psychology*, 74, pp 72-80.

MARTIN, J., O'MUIRCHEARTAIGH, C. & CURTICE, J. (1993). The use of CAPI for attitude surveys: an experimental comparison with traditional methods. *Journal of Official Statistics* (accepted).

MEAD, A. D. & DRASGOW, F. (1993). Equivalence of computerized and paper-and-pencil cognitive ability tests: a meta-analysis. *Psychological Bulletin*, 114, pp 449-458.

NICHOLLS, W. L. II & GROVES, R. M. (1986). The status of computer-assisted telephone interviewing: Part 1- introduction and impact on cost and timeliness of survey data. *Journal of Official Statistics*, 2, pp 93-115.

OLSEN, R. J. (1992). The effects of computer-assisted interviewing on data quality. Paper presented at the fourth Social Science Methodology Conference, Trento.

PARKS, B. T., MEAD, D. E. & JOHNSON, B. L. (1985). Validation of a computer-administered marital adjustment test. *Journal of Marital and Family Therapy*, 11, 207-210.

PORST, R., SCHNEID, M. & VAN BROUWERSHAVEN, J. W. (1994). Computer-assisted interviewing in social and market research. In I. Borg & P. Mohler (Eds.) *Trends and perspectives in empirical social research*. Berlin: Walter de Gruyter.

POULSEN, C. S. (1993). Artificial intelligence applied to computer-aided interviewing. *Proceedings of the ESOMAR Symposium on Information-based decision-making in marketing*, Paris 1993.

REZMOVIC, V. (1977). The effects of computerized experimentation on response variance. *Behaviour Research Methods & Instrumentation*, 9, pp 144-147.

RIEDE, T. & DORN, V. (1991). *Zur Einsetzbarkeit von Laptops in haushaltsbefragungen in der Bundesrepublik Deutschland* [In German: Acceptance of laptops for household surveys in Germany]. Wiesbaden: Statistisches Bundesamt. Heft 20 der Schriftenreihe Ausgewählte Arbeitsunterlagen zur Bundesstatistik.

SALTZMAN, A. (1992). Improving response rates in Disk-by-Mail surveys. *Sawtooth Software Conference Proceedings*. Evanston: Sawtooth Software.

SAMUELS, J. (1994). From CAPI to HAPPI: a scenario for the future and its implications for research. *Proceedings of the ESOMAR Congress.*

SARIS, W. E. (1989). A technological revolution in data collection. *Quality & Quantity*, **23**, pp 333-349.

SARIS, W. E. (1991). *Computer-assisted interviewing*. Sage Quantitative Applications in the Social Sciences no 80. Newbury Park: Sage.

SEBESTIK, J., ZELON, H., DEWITT, D., O'REILLY, J. M. & MCCOWAN, K. (1988). Initial experiences with CAPI. Paper presented at the US Bureau of the Census Annual Research Conference, Washington, DC.

SNIJKERS, G. J. M. E. (1992). Computer-assisted interviewing: telephone or personal? A literature study. In A. Westlake *et al.* (Eds.) *Survey and statistical computing*. Elsevier Science Publishers.

SPAETH, M. A. (1987). CATI facilities at survey organizations. *Survey Research*, **18**, pp 18-22.

SPERRY, S., BITTNER, D. & BRANDEN, L. (1991). Computer-assisted personal interviewing on the current beneficiary survey. Paper presented at the AAPOR 1991 Conference, Phoenix, Arizona.

SPROULL, L. & KIESSLER, S. (1991). Computers, networks and work. *Scientific American*, pp 84-91.

STATISTICS SWEDEN (1989). Computer-assisted data collection in the labour force surveys. Report of technical tests. Stockholm: Statistics Sweden.

THORNBERRY, O., ROWE, B. & BIGGAR, R. (1991). Use of CAPI with the US National Health Interview Survey. *Bulletin de Méthodologie Sociologique*, **30**, pp 27-43.

VAN BASTELAER, A. M. L., KERSSEMAKERS, F. A. M. & SIKKEL, D. (1987). A test of The Netherlands continuous labour force survey with hand-held computers: interviewer behaviour and data quality. In *CBS-Select 4; Automation in survey processing*. Den Haag: Staatsuitgeverij.

VAN DOORN, L. (1987). Het gebruik van microcomputers in panelonderzoek [The use of microcomputers in panel surveys). *Jaarboek van de Nederlandse Vereniging van Marktonderzoekers 1987-88 [Yearbook of the Dutch Association for Market Research]*, pp 9-21.

VAN DOORN, L.T. & HESS T. (1989). Keeping panel respondents fit and willing: using computerised interviewing in panel research to decrease the burden of respondents and improve the quality of the data. *Proceedings of the ESOMAR Congress*.

WATERTON, J. J. (1984). Reporting alcohol consumption: the problem of response validity. *Proceedings of the section on survey research methods of the American Statistical Association*, pp 664-669. Washington DC: ASA.

WATERTON, J. J. & DUFFY, J. C. (1984). A comparison of computer interviewing techniques and traditional methods in the collection of self-report alcohol consumption data in a field survey. *International Statistical Review*, **2**, pp 173-182.

WEEKS, M. F. (1992). Computer-assisted survey information collection: a review of CASIC methods and their implication for survey operations. *Journal of Official Statistics*, **4**, pp 445-466.

WILSON, B. (1989). Disk-by-Mail surveys: three year's experience. *Sawtooth Software Conference Proceedings*. Evanston: Sawtooth Software.

WITT, K. J. & BERNSTEIN, S. (1992). Best practices in Disk-by-Mail surveys. *Sawtooth Software Conference Proceedings*. Evanston: Sawtooth Software.

WOIJCIK, M. S., BARD, S. & HUNT, E. (1992). Training field interviewers to use computers: a successful CAPI training program. Chicago: NORC. Information Technology in Survey Research Discussion Paper 8 (Also presented at the 1991 AAPOR Conference, Phoenix, Arizona).

ZANDAN, P. & FROST, L. (1989). Customer satisfaction research using Disk-by-Mail. *Sawtooth Software Conference Proceedings*. Evanston: Sawtooth Software.