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Nursing Acceptance of a Speech-Input Interface: A Preliminary Investigation

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Many new technologies are being developed to improve the efficiency and productivity of nursing staffs. User acceptance is a key to the success of these technologies. In this article, the authors present a discussion of nursing acceptance of computer systems, review the basic design issues for creating a speech-input interface, and report preliminary findings of a study of nursing acceptance of a prototype speech-input interface. Results of the study showed that the 19 nursing subjects expressed acceptance of the prototype speech-input interface.
Key words: Computers, Speech-recognition program, Attitude toward computers, Research.

Introduction

Mechanisms for accurate and timely documentation of nursing care are necessary to improve quality assurance and to increase accountability of the provider. If captured at the source—the bedside—documentation can improve nursing productivity (Hughes, 1988). Collecting and recording these data can be a time-consuming task. Therefore, an increasing number of hospitals are planning to automate the documentation process with computer information systems. By computerizing the documentation process, three advantages can be achieved for the nursing staff: 1) minimizing time required for data entry, 2) eliminating redundancies when charting information, and 3) improving the timeliness of the documentation effort (Hughes, 1988).

One important factor that can influence health care personnel (i.e., nursing staff) to accept or reject a computer information system is the quality of the user interface. The quality of interface is normally reflected in the convenience and ease of use of the system (Perreault & Wiederhold, 1990). With the importance of user acceptance in mind, an interface for nursing applications should provide a number of advantages: minimizing interruptions in routine patient care, giving users a sense of control by allowing for brief interactions that convey the logic of how the application works, and using intuitive input techniques that avoid typing (Shortliffe, 1987).

Systems for nursing applications employ special keyboards and pointing devices, such as light pens, touch screens, and mice. But these interface methods were not designed for a nurse at the bedside, a computer user in a busy environment. Speech recognition is successful in a number of hands-busy and eyes-busy domains (Frankish, Jones, Madden, Waight, & Stoddart, 1987; Jones, Frankish, & Hapeshi, 1992). For this reason, researchers have suggested that speech recognition may provide the most natural and acceptable approach to entering patient data (Shiffman, et al., 1991).

Recent developments in speech recognition technology make it reasonable to consider creating an interface that permits nursing staff to enter patient data by speech. Applications recently developed or under investigation in nursing or similar health care domains include the following examples:

- A speech-controlled system for generating radiology reports (Robbins, Horowitz, & Srinivasan, 1987).
- A voice-activated word processor that gathers emergency department documentation from physicians (Linn, Rubenstein, Bowler, & Dixon, 1992).
- A history-taking system that uses continuous speech recognition and permits a patient to enter basic

symptoms by engaging in dialogue with the software (Johnson, Poon, Shiffman, Lin, & Fagan, 1992).

- A speech-recognition system for bedside entry of patient data in a pediatric intensive care unit (Petroni, et al., 1991).
- A continuous speech interface for the Quick-Medical Reference system, which allows physicians to input spoken descriptions of physical-examination findings or observations (Shiffman, Lane, Johnson, & Fagan, 1992).
- An isolated-word speech-recognition system for bedside terminals that permits entry of patient data (The Nursing VOICE System, Bound Information Technology Solutions, St. Louis, MO).

Because the quality (i.e., ease of use) of the user interface is an important factor in the acceptance or rejection of a computer system by the nursing staff, we provide a short explanation of design issues in speech-recognition interface technology, survey nursing acceptance of computer and information systems, and conclude with the description and results of a small study that examines nursing acceptance of a prototype speech-recognition interface system that enters cardiovascular assessment data into a patient database.

Review of Literature

This review of literature summarizes two items: 1) the design issues in speech-recognition interface technology, and 2) nursing acceptance of computer and information systems.

Speech-Recognition Technology

There are six design issues that should be considered when creating a speech-recognition interface: 1) the vocabulary size and composition; 2) the grammar or word ordering; 3) the feedback mechanism; 4) the speaker dependence (i.e., the number of speakers able to use the speech-recognition system); 5) the connectivity of the words uttered by the user; and 6) the interface environment (Dillon & DeHaemer, 1992). Each of these issues is inter-related and must be considered when designing a speech interface.

Current speech systems impose language restrictions on users, such as limited vocabulary size and constrained grammar. The vocabulary size and composition is a major concern when recognition accuracy is vital to the application. Vocabularies may range from 10 to 35,000 words. Small vocabularies with dissimilar words have higher recognition accuracy. As the vocabulary increases in size, and similar-sounding words are added, recognition accuracy declines. In addition, as more words are added, the opportunity increases for expansion and alteration of the grammar or word order. A speech-recognition system with limited grammar, commonly called constrained grammar, may improve the accuracy of the recognition systems. A grammar is required to limit the amount of computer power necessary for a word search and to prevent confusion of similar-sounding words. However, by increasing grammatical constraints on the user's spoken utterances, the naturalness of the interaction is reduced. This reduction in naturalness may prevent effective and comfortable interactive dialogue for the user.

Commercially available speech-recognition systems provide three forms of feedback. The first is an audio beep of differing tones for positive or negative responses. For example, if a word or phrase is recognized accurately, the system responds with a high-pitched beep. Conversely, if a word is not recognized correctly, the system responds with a low-pitched beep. The second form of feedback is an audio beep for a correctly recognized positive utterance and no response for an unrecognized utterance. The third form of feedback is the most advanced and includes synthesized speech output. In this form of feedback, the application designer provides the synthesized words used for positive or negative responses.

All speech-recognition systems use some kind of speaker model to characterize the speech that can be recognized. A speaker-dependent speech-recognition system requires the user to provide voice models by enrolling or training the recognizer for each spoken word. A speaker-independent system provides generic models (i.e., voice samples developed from a large speaker population) that have a lower recognition accuracy, but do not need the storage space for individual word models.

Speech systems differ in the amount of continuous words they allow. Some systems allow "connected" speech, in which the user is permitted to speak multiple words or even a long sentence. Other speech systems only permit the utterance of one isolated word or a short phrase at a time. Connected speech, often called continuous speech, permits the user to utter a stream of words in a natural way. The speech recognizer identifies speech segments even though the utterance may be co-articulated (i.e., word boundaries are difficult to identify) or poorly articulated (i.e., the slurring of articles, prepositions, or pronouns). Isolated speech is less difficult to recognize than continuous speech and most often consists of single-word or short phrases (i.e., two to four words that are pronounced as if they are a single word).

The environment may cause the user's utterances to be difficult to recognize. Ambient noise, such as fans, hospital equipment and monitors, television sets, and spoken conversation by others in the vicinity of the microphone may cause misrecognitions. Recently, improvements in

pattern-matching technology and directional microphones with noise-cancellation features have improved recognition and have reduced the need for quiet environments. In fact, one of the most successful applications of speech recognition is airline baggage sorting, which takes place along an assembly line filled with noise and clatter from equipment and motorized vehicles.

Nursing Acceptance of Computer and Information Technology

User acceptance and/or use of computer technology is an important component of system implementation in nursing. But, as in other fields, there is a dearth of empirical studies in the area of user acceptance of the technology. Surprisingly though, nurses' attitudes toward computers have been studied extensively. Much of the published research in this area has sought a relationship between particular attributes, such as age or education, and nurses' attitudes toward information technology.

A possible link between attitude and computer use or acceptance has been studied minimally in nursing. Aydin (1987) found no relationship between nurses' attitudes toward a specific system and self-reported system use. However, the validity of this finding is doubtful, because attitude was measured by one item.

Thomas (1988) asserted that a positive attitude toward computing was essential if nurse educators and practitioners are to use computers optimally. She developed and tested parallel forms of a tool to measure nurses' attitudes toward computing in all areas of nursing (research, administration, practice, and education). This tool was administered to 48 third-year university students before and after receiving computer technology in nursing content (Thomas, Delaney, & Weiler, 1992). The results included a significant relationship between the pretest attitude measure and a skills competency test ($r = .407$, $p < .05$) (p. 168). The authors also reported a significant positive relationship between attitude scores and an expectation of future heavy use of computers. Both of these findings appear to support the idea that use or acceptance of computers is related to attitude and potential usefulness of the technology.

A study of the relationship of use of computers in nursing to one aspect of attitude—work excitement—was reported (Ngin, Simms, & Erbin-Roesemann, 1993). Work excitement was defined as "an individual's personal enthusiasm and interest in work" (p. 128). A convenience sample of 268 nurses was surveyed to discern if computer users and nonusers differed in their perception of exhausting aspects of nursing, excitement about work, excitement about computer use, and whether computers would make their work easier. The results revealed that "nurses who classify themselves as having expert (computer) skills had significantly higher levels of work excitement than those nurses who were novices, ($F = 5.937$; degrees of freedom = 2, 266; $p < .05$) or had no experience with the computer" (p. 130). Nurses also reported that computers made their work easier and a great number requested bedside terminals for documentation and assessment.

Although user acceptance of computer technology is of utmost concern in system implementation, this area of research is lacking in nursing. Other related areas have been studied as mentioned above. No published reports are available in nursing on acceptance of speech-input interfaces, specifically.

Statement of the Problem

The purpose of this study was to examine nursing acceptance of a prototype speech recognition interface system for entering cardiovascular assessment data. We did this by using two questionnaires: 1) a computer-acceptance questionnaire administered to each subject after completion of the first and fourth physical assessment task (each of which provide an interaction with the speech-input interface), and 2) a computer-attitude questionnaire administered before and after the study. Both questionnaires have been used extensively in the speech-interface literature (Casali, Williges, & Dryden, 1990; Zoltan-Ford, 1991) and are considered reliable indicators of computer acceptance and attitude.

Methodology

Subjects

The subjects that volunteered for this study were baccalaureate-prepared registered nurses, nursing students (i.e., fourth-year nursing students with some nursing experience), and baccalaureate nursing faculty. The nurses had differing amounts of actual nursing experience, ranging from only educational internships to 20 years. There were two male and 17 female subjects, and they ranged from 21 to 50 years of age.

Hardware, Software, and Vocabulary Design

A Compaq DeskPro 386s (Compaq, Houston, TX) with a Verbex 6000 speaker-dependent connected-speech recognition board and audio output (Verbex, Edison, NJ) acted as the speech-input interaction system. The system included a head-mounted microphone with one earpiece for feedback.

To create the speech-input interface software, five nurse practitioners performed a "Wizard Experiment" (talked through a physical assessment as if entering patient data into a natural-language voice-processing computer system) (Rudnicky, 1990). Audio tapes were made of the Wizard Experiment. The tapes were transcribed to acquire the natural vocabulary and grammar spoken by the nurse practitioners while performing the task. These transcripts were then coded into a speech-input interface using the Verbex Voice Systems development grammar (Verbex, Edison, NJ) (Figure 1). The speech-input interface contained 103 vocabulary words and between two and six possible grammar options for each assessment item. By using a Wizard Experiment we were able to capture the user's interaction style, structure, and vocabulary (Rudnicky & Sakamoto, 1989). As recommended in the literature, the words and word-order chosen for the speech-input interface were tailored specifically for the application (Michaelis, Chapanis, Weeks, & Kelly, 1977).

Experimental Design

The instrument used to study the changes in interface acceptance consisted of a set of 12 bipolar adjective rating scales of seven intervals each and a concluding 13th seven-interval scale for overall acceptability (Casali, et al., 1990). Scale items were as follows: fast/slow, accurate/inaccurate, consistent/inconsistent, pleasing/irritating, dependable/undependable, natural/unnatural, complete/incomplete, comfortable/uncomfortable, friendly/unfriendly, facilitating/distracting, simple/complicated, and useful/useless (Figure 2).

To validate the data from the computer-acceptance questionnaire, a Spearman rank-order correlation coefficient was computed for each of the 12 bipolar scales, with the 13th overall acceptable/unacceptable scale (Siegel & Castellan, 1988). All scales were highly correlated ($r_s > .51$, $p < .013$) with the overall acceptable/unacceptable scale, and thus, were considered attributes of acceptability. Because acceptability was of primary interest, a single measure of acceptability, an acceptability index (AI), was developed using the procedure reported by Casali et al. (1990). The AI was defined as the sum of the scale responses for the 12 bipolar scales for each subject under each treatment condition. The AI ranged from 12 for high acceptability to 84 for low acceptability.

The instrument used to study the changes in computer-attitude consisted of a set of 15 bipolar adjective rating scales of seven intervals each (Zoltan-Ford, 1991). The computer-attitude questionnaire scale items were as follows: personal/impersonal, simple/complicated, helpful/hindering, systematic/random, easy/difficult, forgiving/unforgiving, obedient/bossy, cooperative/obstinate, nonthreatening/threatening, intelligent/simple-minded, pleasing/disgusting, flexible/inflexible, satisfying/frustrating, calming/anxiety-provoking, and obliging/demanding (Figure 3). Zoltan-Ford (1991) found this instrument to be reliable when determining changes in the user's computer attitude while entering data into a speech-interface checkbook exercise.

Task completion time, number of nonrecognitions, number of misrecognitions, and items skipped were collected during the study, but were not examined unless an irregularity was found in the user-acceptance or user-attitude data. Task completion time was identified as the time from when the subject began to assess the patient until all data were entered into the speech-input interface. Number of nonrecognitions (when the subject uttered a word not in the vocabulary or a word in the vocabulary that was not recognized by the system), number of misrecognitions (when a subject uttered a proper word or phrase from the vocabulary and the speech recognition system recognized the utterance in-

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respirations are .RESP and regular
respirations are .RESP good_volume
respirations are .RESP per_minute and regular
respirations are .RESP per_minute rhythm regular

pulse is .PULSE and regular
radial pulse is a rate_of .PULSE with good_volume
pulse .PULSE per_minute rhythm regular
pulse is .PULSE per_minute and regular

blood pressure .PRESSURE1 over .PRESSURE2
.PRESSURE1 over .PRESSURE2 .OUTCOME blood pressure
blood pressure is .OUTCOME .PRESSURE1 over .PRESSURE2

carotid pulse .OUTCOME
carotid pulse .PULSE strong and regular
.OUTCOME bruits heard over carotid arteries

apex impulse .OUTCOME
.OUTCOME apex impulse

parasternal impulse .OUTCOME
parasternal artery pulsations .OUTCOME
checking parasternal impulse .OUTCOME

pulmonary artery pulsation .OUTCOME

first heart sound .OUTCOME
second heart sound .OUTCOME
third heart sound .OUTCOME
.OUTCOME third heart sound
fourth heart sound .OUTCOME
.OUTCOME fourth heart sound

.OUTCOME click
click .OUTCOME
.OUTCOME extra clicks or murmurs

systolic murmur .OUTCOME
.OUTCOME systolic murmur
.OUTCOME systolic or diastolic murmurs
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Figure 1. A sample vocabulary and grammar.

QUESTIONNAIRE

Rate your satisfaction with the interface by circling the appropriate number for the scaled items below.

1. fast							slow
	1	2	3	4	5	6	7
2. accurate							inaccurate
	1	2	3	4	5	6	7
3. consistent							inconsisten
	1	2	3	4	5	6	7
4. pleasing							irritating
	1	2	3	4	5	6	7
5. dependable							undependable
	1	2	3	4	5	6	7
6. natural							unnatural
	1	2	3	4	5	6	7
7. complete							incomplete
	1	2	3	4	5	6	7
8. comfortable							uncomfortable
	1	2	3	4	5	6	7
9. friendly							unfriendly
	1	2	3	4	5	6	7
10. facilitating							distracting
	1	2	3	4	5	6	7
11. simple							complicated
	1	2	3	4	5	6	7
12. useful							useless
	1	2	3	4	5	6	7
Overall Evaluation							
13. acceptable							unacceptable
	1	2	3	4	5	6	7

Figure 2. The questionnaire used to gather changes in computer-acceptance data (Casali, Williges, & Dryden, 1990).

correctly), and items skipped were gathered by observation, review of the input file, and analysis of audio tapes recorded during the study.

Procedure

Each subject's session was conducted individually. Before participating in the study, a subject completed a pre-experimental computer-attitude questionnaire (Figure 3). Each subject was then told that the purpose of the study was to test a newly developed computer interface that permits a nurse to enter patient data into a computer system by talking. A subject enrolled voice models for the speaker-dependent system first by isolated, and then by connected speech. During enrollment, a subject was introduced to the speech-input vocabulary and grammar that would be used during the study. Each isolated word in the vocabulary was trained a minimum of two times. Then all connected-word phrases also were trained. After a subject completed the enrollment procedure, a practice trial with the interface, and four examinations for the study, a second computer-attitude questionnaire was administered.

For the hands-busy and eyes-busy task, each subject performed a cardiovascular physical assessment for a patient. The patient was a volunteer that laid quietly as if unable to respond to commands or requests from the subject. Twenty-one data items were gathered by the subject, including respirations and blood pressure, and various pulses, impulses, and heart sounds. For simplicity, data items were limited to cardiovascular assessments gathered by observation, sphygmomanometer, and stethoscope. A shortened form of a standard cardiovascular examination guide sheet, containing only the 21 data items, was provided for each subject (Figure 4). While performing the assessment, data were entered into the speech-input interface by a head-mounted microphone. Because no visual feedback was available to the subject, feedback was provided by an audio beep when data were received and were recognized by the system. If the system did not recognize a spoken utterance, a subject was instructed to attempt to get recognition by repeating all of the items five times. A subject performed four complete cardiovascular physical assessments using the speech-input interface to

QUESTIONNAIRE

Rate "How you feel about computers" by circling the appropriate number for the scaled items below. Select 4 if neutral.

1. personal							impersonal
	1	2	3	4	5	6	7
2. simple							complicated
	1	2	3	4	5	6	7
3. helpful							hindering
	1	2	3	4	5	6	7
4. systematic							random
	1	2	3	4	5	6	7
5. easy							difficult
	1	2	3	4	5	6	7
6. forgiving							unforgiving
	1	2	3	4	5	6	7
7. obedient							bossy
	1	2	3	4	5	6	7
8. cooperative							obstinate
	1	2	3	4	5	6	7
9. unthreatening							threatening
	1	2	3	4	5	6	7
10. intelligent							simple-minded
	1	2	3	4	5	6	7
11. pleasing							disgusting
	1	2	3	4	5	6	7
12. flexible							inflexible
	1	2	3	4	5	6	7
13. satisfying							frustrating
	1	2	3	4	5	6	7
14. calming							anxiety-provoking
	1	2	3	4	5	6	7
15. obliging							demanding
	1	2	3	4	5	6	7

Figure 3. The pre- and post-test questionnaire used to gather computer-attitude data (Zoltan-Ford, 1991).

PHYSICAL EXAMINATION OF THE CARDIOVASCULAR SYSTEM
Guide Sheet

INSTRUCTIONS: Please state the test and the response/result. Indicate normal and/or abnormal results for each item during the cardiovascular physical exam.

Respiratory
 a. Rate: _____/min.
 b. Rhythm: _____
Pulse
 a. Rate: _____/min.
 b. Rhythm: _____
Blood Pressure: _____/_____mm Hg
If abnormal:
 a. Leg: _____/_____mm Hg
 b. Standing: _____/_____mm Hg

NORMAL		ABNORMAL
____	Carotid pulse	____
____	Apex impulse	____
____	Parasternal impulse	____
____	Pulmonary artery pulsation	____
____	First heart sound	____
____	Second heart sound	____
____	Third heart sound	____
____	Fourth heart sound	____
____	Click	____
____	Systolic murmur	____
____	Diastolic murmur	
____	Edema	____
	Right leg 1 2 3 4	
	Left leg 1 2 3 4	
____	Thrombophlebitis	____
____	Clubbing	
____	Cyanosis	

Figure 4. The cardiovascular-exam guide sheet provided to all subjects.

record assessment results. To determine changes in computer acceptance, a computer-acceptance questionnaire was completed after the first and fourth assessments (Figure 2).

Results

Two subjective ratings questionnaires were used to assess the user's acceptance and attitude of the speech-input interface. They were a computer-attitude questionnaire (Zoltan-Ford, 1991) and a computer-acceptance questionnaire (Càsali et al., 1990). The results for each of these questionnaires are presented below. The task completion time, number of nonrecognitions, number of misrecognitions, and the number of times a subject skipped a response were counted. No irregularities were noted in any of these items. These four items are more an evaluation of the speech-recognition system than an analysis of the user's acceptance of the speech-input interface. For these reasons, they will not be discussed in the results.

Computer Acceptance

The computer-acceptance questionnaire (Figure 2) was administered after the first and fourth physical assessments. An AI was calculated for each subject from the sum of the 12 bipolar scales. For the nonparametric data analysis, Wilcoxon's signed-rank test was used. The AI displayed a significant positive change in acceptance after using the speech-input interface ($Z = -3.1284$, two-tailed $p = .0018$). These findings indicate that, as a user interacts with the speech-input interface, the interface becomes more acceptable.

Computer Attitude

The computer-attitude questionnaire (Figure 3) consisted of an attitude scale of 15 bipolar adjective pairs (Zoltan-Ford, 1991). Because the data were ordinal in nature, Wilcoxon's signed-rank test was used for the data analysis. The mean responses to each subject's pre- and postexperimental questionnaire did not differ statistically after gaining experience with the interface ($Z = -1.4154$, two-tailed $p = .1570$). This outcome may be seen as a positive reaction to the speech-input interface, because subjects did not react negatively to the interface after interacting for an extended period.

Discussion

Collecting and recording patient data are key responsibilities for the nursing professional. Automating this task with a computer information system can provide certain advantages if the automated applications are accepted by the nursing staff. Acceptance by the nursing staff often is based on the convenience and ease of use of the computer interface. As identified by Ngin et al (1993), bedside systems for documentation are highly requested by nurses. The addition of a speech-input interface that frees a nurse's hands and eyes may fill the current void for a well-accepted, productivity-enhancing, and nursing-specific computer interface.

In this article, we attempted to provide insight into speech recognition technology for nursing applications, to gain an understanding of nursing acceptance of computer and information technology, and to examine the acceptance of nursing staff when entering patient data with speech input. The speech-input interface may soon be a common technology found in most hospitals. As nursing

acceptance increases for computer technology, acceptance for a speech interface also will increase. As the results of the current study show, user acceptance improves as a user gains experience with a speech-input system.

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