Research and Publication Request

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Client: Bill Clymer, PEN International
Topic: research, publications and guidelines related to the use of technology to provide remote captioning or interpreting services for deaf students in post secondary settings

Search Terms: C.A.R.T. (Communication Access Real-time Translation), Real-time Captioning, Real-time Speech Transcription;

Contents:

Introduction and Websites
Articles - Research

Introduction and Websites

Communication Access Realtime Translation (CART) is the instant translation of the spoken word into English text using a stenotype machine, notebook computer and realtime software. The text appears on a computer monitor or other display. This technology is primarily used by people who are late-deafened, oral deaf, hard-of-hearing, or have cochlear implants. Culturally deaf individuals also make use of CART in certain situations. Please keep in mind that CART is also often referred to as realtime captioning.

Communication Access Information Center: http://www.cartinfo.org/

E-Michigan Deaf and Hard of Hearing People: http://www.michdhh.org/assistive_devices/cart.html

Articles - Research

Communication Access Real-time Translation (CART) Captionist from University of California, LA. (2003).
http://www.chr.ucla.edu/chr/comp/webdocs/ClassSpecAlpha_files/pdfclassspecs/captionist.pdf

Susanne Wagner (2005). Intralingual speech-to-text-conversion in real-time: Challenges and Opportunities. Challenges of Multidimensional Translation: Conference Proceedings.
http://www.translationconcepts.org/pdf/MuTra_2005_Proceedings.pdf#page=214

> Intralingual speech-to-text-conversion is a useful tool for integrating people with hearing impairments in oral communication settings, e. g. councelling interviews or conferences. However, the transfer of speech into written language in real time requires special techniques as it must be very fast and almost 100% correct to be understandable. The paper introduces and discusses different techniques for intralingual speech-to-text-conversion.

Anna C. Cavender (2008). Using Networked Multimedia to Improve Academic Access for Deaf and Hard of Hearing Students. Online document: http://dhhcybercommunity.cs.washington.edu/publications/annacc_generals_doc.pdf

Deaf and hard of hearing students experience barriers that make access to mainstream universities a challenge. Educational technology has the potential to better include these students in the academic mainstream. This paper begins by outlining historical trends in education for deaf students because understanding the unique characteristics and experiences of members of the deaf community will be crucial for successful design. We then discuss current trends in educational technology in general, especially those that will ultimately be made accessible or compatible with the needs of deaf students. Finally, this paper describes the author's proposed thesis work: the development and evaluation of a classroom platform for deaf and hard of hearing students to access remote interpreters and captionists, avoid visual dispersion, and facilitate classroom interaction.

Kheir, Richard and Way, Thomas (2007). Inclusion of Deaf Students in Computer Science Classes using Real-time Speech Transcription: http://delivery.acm.org/10.1145/1270000/1268860/p261-kheir.pdf?key1=1268860&key2=7919364021&coll=GUIDE&dl=GUIDE&CFID=57738567&CFTOKEN=41315552.

Computers increasingly are prevalent in the classroom, with student laptops becoming the norm, yet some beneficial uses of this widespread technology are being overlooked. Speech recognition software is maturing, and possesses the potential to provide real-time note taking assistance in the classroom, particularly for deaf and hard of hearing students. This paper reports on a practical, portable and readily deployed application that provides a cost-effective, automatic transcription system with the goal of making computer science lectures inclusive of deaf and hard of hearing students. The design of the system is described, some specific technology choices and implementation approaches are discussed, and results of two phases of an in-class evaluation of the system are analyzed. Ideas for student research projects that could extend and enhance the system also are proposed.

Elliot, L & Stinson,M. (2003). C-Print Update: Recent Research and New Technology. NTID Research Bulletin 8(2). https://ritdml.rit.edu/dspace/bitstream/1850/2701/1/NTIDNewsletterWinter2003.pdf

C-Print refers to a family of computer-assisted, speech-to-print technologies. Here, we briefly describe the service and review recent findings and forthcoming enhancements to the system. Since 1990, approximately 1000 deaf and hard-of-hearing students have been supported in educational environments through use of C-Print and over 500 individuals from approximately 350 educational programs in at least 46 states and 4 foreign countries have completed the month-long training to become a C-Print captionist. C-Print has been widely disseminated beyond NTID and is now frequently requested by deaf and hard-of-hearing students around the world.

Smith, Duane. (2001). CART in the Classroom: How to Make Realtime Captioning Word for You. Instructional Technology and Education of the Deaf Supporting Learners, K – College: An International Symposium, Rochester, N.Y. http://www.rit.edu/~techsym/papers/2001/T10B.pdf

Communication Access Realtime Translation (CART) reporting has gained increasing prominence as an assistive technology. CART provides a verbatim translation of the lecture, allowing students with a hearing loss to fully participate in class. Find out about the benefits of CART in the educational setting and experience a demonstration of this equalizing technology.

Fifield, M. Bryce; & Webster, JoLynn (2001). Realtime Remote Online Captioning: An Effective Accomodation for Rural Schools and Colleges . Instructional Technology and Education of the Deaf Supporting Learners, K – College: An International Symposium, Rochester, N.Y. http://www.rit.edu/~techsym/papers/2001/W11C.pdf

The Realtime Remote Online Captioning System (RROCS) developed by Fifield and his colleagues at the North Dakota Center for Persons with Disabilities (http://ndcpd.org) provides a tool for delivering captioning services to rural and isolated locations. Audio from the teacher and the classroom is captured via a lapel or handheld microphone and transmitted to a classroom computer running the RROCS software. The software digitizes the audio and transmits it via the Internet to an off- site captionist who is also running the RROCS software. The software plays the classroom audio for the captionist who transcribes it either directly into the RROCS or by using a commercial transcription program such as GlobalCat. The transcribed text is transmitted back to the classroom where it is displayed for the student. The transcript is also posted to a password protected web site for later retrieval or emailed to the teacher and/or student.

Veazey, Barbara & McInturff, Paul (2006). Establishing a Realtime Captioning Program: Designed to Meet the Needs of 28 Million Deaf and Hearing Impaired Americans. Community College Journal of Research & Practice 30(2) p157-158. http://web.ebscohost.com/ehost/pdf?vid=8&hid=4&sid=16991b28-f456-4209-ad56-6139b03245ee%40sessionmgr9

With the ability to provide open access at the local, regional, and statewide levels, community colleges are proving that they are truly the people's college. By revising existing programs in a short period of time to meet the needs of 28 million deaf and hearing impaired Americans, they are again proving that they can provide qualified graduates for new jobs demanded by the work force. This brief article describes a court reporting program at the West Kentucky Community and Technical College that has made the necessary revisions to take it to the level of being able to incorporate the Captioning and Communication Access Realtime Translation Program (CART) into their program.

Elliot, L; Stinsin, M.; McKee, Barbara; Everhart, Victoria; & Francis, Pamela (2001). College Students Perceptions of the C-Print Speech-to-Text Transcription System. Journal of Deaf Studies and Deaf Education 6:4. http://jdsde.oxfordjournals.org/cgi/reprint/6/4/285 .

With the ability to provide open access at the local, regional, and statewide levels, community colleges are proving that they are truly the people's college. By revising existing programs in a short period of time to meet the needs of 28 million deaf and hearing impaired Americans, they are again proving that they can provide qualified graduates for new jobs demanded by the work force. This brief article describes a court reporting program at the West Kentucky Community and Technical College that has made the necessary revisions to take it to the level of being able to incorporate the Captioning and Communication Access Realtime Translation Program (CART) into their program.

Foster, Susan; Long, Gary; & Snell, Karen (1999). Inclusive Instruction and Learning for Deaf Students in Postsecondary Education. Journal of Deaf Studies and Deaf Education 4(3). Oxford University Press, Cambridge. http://jdsde.oxfordjournals.org/cgi/reprint/4/3/225.pdf

This article explores how students who are deaf and their instructors experience mainstream college classes. Both quantitative and qualitative procedures were used to examine student access to information and their sense of belonging and engagement in learning. Instructors were asked to discuss their approach to teaching and any viewed classroom communication and engagement in a similar manner as their hearing peers. Deaf students were more concerned about the pace of instruction and did not feel as much a part of the 'university family' as did their hearing peers. Faculty generally indicated that they made few if any modifications for deaf students and saw support service faculty as responsible for the success or failure of these students. We discuss results of these and additional findings with regard to barriers to equal access and strategies for overcoming these barriers.

Preminger, Jill E.; & Levitt, Harry (1997). Computer-assisted remote transcription (CART): A tool to aid people who are deaf or hard of hearing in the workplace. Volta Review 99(4), p218. http://web.ebscohost.com/ehost/detail?vid=4&hid=116&sid=e7f744c7-b9ff-418b-89c8-af7d58cc52dd%40sessionmgr103

New technologies are needed that will allow people who are deaf or hard of hearing to participate fully in meetings held in the workplace. Computer Assisted Remote Transcription (CART) is a procedure in which a stenographer transcribes a meeting from a remote location. This study investigated the feasibility of the CART system through an experiment and a case study. An experiment was conducted to learn whether a stenographer could transcribe a meeting of up to 10 speakers accurately from a remote location. In the case study, the CART system's usefulness and practicality were investigated in the workplace for a professional with a hearing impairment. The results indicated that, after a short familiarization period, a stenographer should be able to transcribe a meeting of up to 10 speakers with fairly good accuracy, but the results also revealed several problems with the practicality of the CART system in the workplace.

University of California, Los Angeles
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Class Specification – B.15
CART Captionist - 6681

Communication Access Real-time Translation (CART) Captionist

CLASS CONCEPT

CART Captionist

The Communication Access Real-time Translation (CART) Captionist provides a communication link between the hearing impaired or otherwise disabled student and the instructor by transmitting classroom lectures and/or other spoken materials in English into a concurrent display that has been put into a textural format. The captioning service is for the hearing impaired student's individual use and typically does include transcripts of the captioned transcription. The incumbent translates the transmission of what is being said in the student's immediate environment by using a stenography machine that connects to a laptop computer or a textural projection for the use of the student. The CART Captionist employs simultaneous delivery skills word-for-word between the instructor and the student to enable the hearing impaired student to participate in classroom discussions. The incumbent is available for captioning the student's appointments with faculty and may assist faculty and staff members in communicating with the hearing impaired student. The incumbent may be required to caption technical and scientific information, necessitating understanding of related words and phrases that require technical training for comprehension. As called upon, the CART Captionist may provide additional captioning, and may perform other related duties as assigned.

DISTINGUISHING CHARACTERISTICS:

The CART Captionist position is distinguished from the Interpreter/Translator for the Deaf position (Title Code 6680) in that the CART Captionist utilizes specialized equipment to transcribe auditory input; the Interpreter for the Deaf uses sign language to translate the same information. The positions are also distinguished from one another in that they serve different student needs. The positions are similar in that both provide services to enable the student with a hearing impairment to participate in the educational process.

MINIMUM QUALIFICATIONS

CART Captionist

Graduation from high school or a General Education Diploma; comprehensive knowledge of English, proven proficiency in using captioning equipment; or an equivalent combination of education and experience and knowledge and abilities essential to the successful performance of the duties assigned to the position. Requirements for this position typically include proficiency with a dictionary of 26,000 entries and captioning speed up to 180 words per minute. Some positions may require certification by recognized CART Captionist associations and the provision and use of own captioning equipment and software.

Susanne Wagner (Halle)

Intralingual speech-to-text-conversion in real-time: Challenges and Opportunities

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1 The need for real-time speech-to-text conversion
2 The challenges of speech-to-text-conversion in real-time
3 Methods of real-time speech-to text conversion
4 Text adaptation
5 Presentation format
6 Perspectives
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Abstract

Intralingual speech-to-text-conversion is a useful tool for integrating people with hearing impairments in oral communication settings, e. g. councelling interviews or conferences. However, the transfer of speech into written language in real time requires special techniques as it must be very fast and almost 100% correct to be understandable. The paper introduces and discusses different techniques for intralingual speech-to-text-conversion.

1 The need for real-time speech-to-text conversion

Language is a very fast and effective way of communicating. To use language means to express an unlimited amount of ideas, thoughts and practical information by combining a limited amount of words with the help of a limited amount of grammatical rules. The result of language production processes are series of words and structure. Series of words are produced – i.e. spoken or signed – in a very rapid and effective way. Any person can follow such language production processes and understand what the person wants to express if two preconditions are fulfilled the recipients must:

1. know the words and grammatical rules the speaker uses and
2. be able to receive and process the physical signal.

Most people use oral language for everyday communication, i.e. they speak to other people and hear what other people say. People who are deaf or hard-of-hearing do not have equal access to spoken language, for them, precondition 2 is not fulfilled, their ability to receive speech is impaired.

If people who are severely impaired in their hearing abilities want to take part in oral communication, they need a way to compensate their physical impairment[1]. Hearing aids are sufficient for many hearing impairment people. However, if hearing aids are insufficient,

[1] To provide access to oral communication situations for hearing impaired people is an issue of fairness which, in recent years, is increasingly reflected by national governments. In some countries laws stipulate that at least authorities and official institutions provide information in a form which is also accessible for people with an impairment. Consequently, auditory information has to be provided in a way which can also be detected visually or haptically by people with a hearing impairment (cf. S. Wagner et al., 2004).

spoken language has to be transferred into a modality which is accessible without hearing, e.g. into the visual domain.

There are two main methods to transfer auditory information into a visible format. The translation into sign language is one method and it is best for people who use sign language as a preferred language, as e.g. many Deaf people do. However, for people with a hearing disability who do not know sign language, sign language interpreting is not an option — as for many Hard of Hearing people and people who became hearing impaired later in their life or elderly people with various degrees of hearing loss. They prefer their native oral language given in a visible modality. For them, a transfer of spoken words into written text is the method of choice, in other words: they need an intralingual speech-to-text-conversion.

Speech-to-text-translation (audiovisual translation) of spoken language into written text is an upcoming field since movies on DVDs are usually sold with subtitles in various languages. While the original language is given auditorily, subtitles provide a translated version in another language at the same time visually. The audiovisual transfer from the spoken original language into other languages which are presented in the subtitles can be called an interlingual audiovisual translation. Interlingual translation aims at transferring messages from one language into another language. This translation process combines classical interpreting with a transfer from spoken language patterns into written text patterns. Auditory events which are realized as noises or speech melodies would often not be transferred because normally hearing people can interpret them by themselves. Interlingual translation primarily addresses the lack of knowledge of the original language, i.e. the first precondition for understanding language.

The intralingual audiovisual transfer differs in many aspects from the interlingual audiovisual translation between two languages.

First of all, intralingual audiovisual transfer for people with hearing impairments addresses primarily precondition 2, i.e. the physical ability to perceive the speech signals. The aim of an intralingual audiovisual transfer is to provide all auditory information which is important for the understanding of an event or action. Words as well as non-language sounds like noises or hidden messages which are part of the intonation of the spoken words (e.g. irony or sarcasm) need to be transmitted into the visual (or haptic) channel. How this can be achieved best, is a question of present and future research and development (cf. Neves, in this book). Moreover, people with hearing impairment may insist on a word-by-word-transfer of spoken into written language because they do not want a third person to decide which parts of a message are important (and will therefore be transferred) and which parts are not. As a result, intralingual audiovisual transfer for people with hearing impairment might mean that every spoken word of a speech has to be written down and that all relevant auditory events from outside of the speech have to be described, too (interruptions, noises). In the latter case, the intralingual audiovisual transfer would exclusively satisfy the physical ability to perceive the speech signal (precondition 2).

The classical way to realize an intralingual speech-to-text transfer is to stenotype a protocol or to record the event and to transfer it into a readable text subsequently. This post-event transfer process is time-consuming and often difficult, since auditory events easily become ambiguous outside of the actual context. Moreover, the time shift involved in the transfer into a readable text means a delayed access to the spoken words, i.e. it does not help people with hearing impairments in the actual communication situation. However, for counselling interviews, at the doctor's or at conferences, access to spoken information must be given in real-time. For these purposes, the classical methods do not work.

2 The challenges of speech-to-text-conversion in real-time

Real-time speech-to-text-conversion aims at transferring spoken language into written text (almost) simultaneously. This gives people with a hearing impairment, access to the contents of spoken language in a way that they e.g. become able to take part in a conversation within the normal time frame of conversational turn taking. Another scenario for real-time speech-to-text-transfer is a live broadcast of a football match where the spoken comments of the reporter are so rapidly transferred into subtitles that they still correspond to the scene the reporter comments on. An example from the hearing world would be a parliamentary debate which ends with the electronic delivery of the exact word protocol presented to the journalists immediately after the end of the debate. (cf. Eugeni, forthcoming)

This list could be easily continued. However, most people with a hearing disability do not receive real-time speech-to-text services at counselling interviews, conferences or when watching a sports event live on TV. Most parliamentary protocols are tape recorded or written stenotyped and subsequently transferred into readable text. What are the challenges of real-time speech-to-text conversion that make its use so rare?

2.1 Time

A good secretary can type about 300 key strokes (letters) per minute. Since the average speaking rate is about 150 words per minute (with some variance between the speakers and the languages), even the professional typing rate is certainly not high enough to transfer a stream of spoken words into a readable form in real-time. As a consequence, the speed of typing has to be increased for a sufficient real-time speech-to-text transfer. Three different techniques will be discussed in the following section "methods".

2.2 Message Transfer

The main aim of speech-to-text transfer is to give people access to spoken words and auditory events almost simultaneously with the realization of the original sound event. However, for people with limited access to spoken language at a young age, 1:1 transfer of spoken words into written text may sometimes not be very helpful. If children are not sufficiently exposed to spoken language, their oral language system may develop more slowly and less effectively compared with their peers. As a result, many people with an early hearing impairment are less used to the grammatical rules applied in oral language as adults and have a less elaborated mental lexicon compared with normal hearing people (Schlenker-Schulte, 1991; see also Perfetti et al. 2000 with respect to reading skills among deaf readers)[2].

If words are unknown or if sentences are too complex, the written form does not help their understanding. The consequence for intralingual speech-to-text conversion is that precondition 1, the language proficiency of the audience, also has to be addressed, i.e. the written transcript has to be adapted to the language abilities of the audience - while the speech goes on.

Speech-to-text service providers not only need to know their audience, they also have to know which words and phrases can be exchanged by equivalents which are easier to

[2] Apart from people who were born with a more severe hearing impairment, language proficiency might differ also for people with cultural backgrounds different from a majority group, people with other mother tongues or people with learning difficulties.

understand, and how grammatical complexity can be reduced. They need to know techniques of how to make the language in itself more accessible while the information transferred is preserved. Aspects of how language can be made more accessible will be discussed in the following section "text adaptation".

2.3 Real-time presentation of the written text

Reading usually means that words are already written down. Presented with a written text, people will read at their individual reading speed. This, however, is not possible in real-time speech-to-text conversion. Here, the text is written and read almost simultaneously, and the control of the reading speed shifts at least partly over to the speaker and the speech-to-text provider. The text is not fixed in advance, instead new words are produced continuously and readers must follow this word production process very closely if they wants to use the real-time abilities of speech-to-text transfer. Because of this interaction of writing and reading, the presentation of the written text must be optimally adapted to the reading needs of the audience. This issue will be discussed at the end of the paper in section "presentation format".

The challenges of real-time speech-to-text conversion can now be summarized as follows:

1. to be fast enough in producing written language that
2. it becomes possible to meet the expectations of the audience with respect to the characteristics of a written text. Word-by-word transfer enhanced by a description of auditory events from the surroundings as well as adaptations of the original wording into easier forms of language must be possible. Moreover,
3. a successful real-time presentation must match the reading abilities of the audience, i.e. the written words must be presented in a way that is optimally recognizable and understandable for the readers.

3 Methods of real-time speech-to text conversion

There are three methods that are feasible when realizing (almost) real-time speech-to-text transfer: speech recognition, computer assisted note taking (CAN) and communication access (or computer aided) real-time translation (CART). The methods differ

1. in their ability to generate exact real-time transcripts.
2. with respect to the conditions under which these methods can be properly applied and
3. with respect to the amount of training which is needed to become a good speech-to-text service provider.

3.1 Speech recognition

Automatic speech recognition (ASR) technologies today can correctly recognize and write down more than 90% percent of a long series of spoken words for many languages. However, even this high percentage is not sufficient for speech-to-text services, since 96+x% correctness is needed to provide a sufficient message transfer (Stinson et al. 1999: accuracy). Moreover, even the 90+x% accuracy in automatic speech recognition does not occur by itself. In order to be recognized, the speaker has to train the speech recognition system in advance with her/is voice and speaking characteristics. Some regional speaking characteristics (dialects) are generally only poorly recognized, even after extensive training. Physical changes in voice quality (e.g. from a flu) can result in poorer recognition results. The reason for this is that the speech recognition process is based on a match of physical parameters of the actual speech signal with a representation which was generated on the basis of a general phonetic model of language and the phonetic and voice data from the individual training sessions. If the individual physical parameters differ from those of the training sessions, recognition is less successful. Moreover, if background noise decreases the signal-to-noise-ratio, accuracy might go down to below 80 percent.

However, speech recognition systems can meet challenge number 1 (writing speed) under good circumstances. In this case, the recognition rate of ASR would in principle be high enough to transfer every spoken word into written text in real-time. But there are limitations which have to be taken into account. The most restrictive factor is that automatic speech recognition systems are not (yet) capable of recognizing phrase- and sentence boundaries (but see Leitch et al. 2002). Therefore, the output from an automatic speech recognition system is a stream of words without any comma or full stop. Moreover, the words would not be assigned to the different speakers. An example from Stuckless (1999) might illustrate how difficult it is to understand such a stream of words:

> "why do you think we might look at the history of the family history tends to dictate the future okay so there is some connection you're saying what else evolution evolution you're on the right track which changes faster technology or social systems technology." (Stuckless 1999)

Automatic speech recognition today fails as far as challenge 3 is concerned.: Although the single words are readable, the output of automatic speech recognition systems is almost not understandable for any reader.

The short-term solution for this problem is that a person, who has trained her/is speech recognition system extensively with his/her speaking characteristics, has to re-speak the speech of the speaker with explicit punctuation commands and speaker identification. With re-speaking, speech recognition is an option especially for live subtitling and conferences where the speech-to-text conversion can be made in a studio or sound shielded room. With respect to the need of an excellent signal-to-noise-ratio, it is certainly not an option for noisy surroundings.

Re-speaking has advantages though. It makes it possible to adapt the spoken language for an audience with limited oral language proficiency. This would not be possible with automatic speech recognition.

Real-time speech-to-text conversion with speech recognition systems does not require special technical knowledge or training except for the fact that the SR- system has to be trained. For the user it is sufficient to speak correctly. However, linguistic knowledge and a kind of "thinking with punctuation" is necessary to dictate with punctuation marks.

Summary of speech recognition

Automatic speech recognition is not yet an option for speech-to-text transfer since phrase- and sentence boundaries are not recognized. However, speech recognition can be used for real-time speech-to-text conversion if a person re-speaks the original words. Re-speaking is primarily necessary for including punctuation and speaker identification but also for adapting the language to the language proficiency of the audience. Apart from an intensive and permanent training of the speech recognition engine, no special training is required. A sound-shielded environment is useful. The use of a speech recognition systems does not require any special training. Linguistic knowledge, however, is necessary for the chunking of the words and for adaptations of the wording.

3.2 Computer-assisted note taking (CAN)

With computer-assisted note taking (CAN), a person writes into an ordinary computer what a speaker says. However, as was discussed earlier, even professional writing speed is not sufficient to write down every word of a speech. To enhance writing speed, abbreviation systems are used in computer-assisted note taking which minimize the amount of key strokes per word. The note taking person types abbreviations or a mixture of abbreviations and long forms. An abbreviation-to-long-form dictionary translates the abbreviations immediately into the corresponding long form. On the screen, every word appears in its long form.

Realizations of CAN systems are widespread. On the one hand, small systems are incorporated in almost every word processing software. The so called "auto correction" translates given or self defined abbreviations into the corresponding long forms. On the other hand, there are very elaborated and well developed systems like e.g. C-Print which has been developed at the National Technical Institute for the DEAF at Rochester Institute of Technology (RIT 2005). This system uses phonetic rules to minimize the key strokes for every word. After a period of training with the system, the captionist is able to write with a higher speed. This allows for a high quality message transfer. However, the writing speed is still limited so that word-for-word transcripts are rather unusual, even with C-Print. With CAN-systems like C-Print, a message-to-message rather than a word-for-word transfer is produced.

The efficiency of CAN systems is mainly determined by the quality of the dictionary which translates the short forms into the corresponding long forms. The better the dictionary, the higher the typing speed potential.

Individually made dictionaries are mostly a collection of abbreviations like 'hv' for 'have' and 'hvt' for 'have to' etc. However, this kind of dictionary is limited insofar as the user has to know every abbreviation. Consequently, the amount of time which is needed for people to learn and to prevent them from forgetting the abbreviations once learned increases with the increase in the size of the dictionary.

Elaborated systems like C-Print use rule-based short-to-long translations. Here, the captionist has to learn the rules of transcription. One rule could be that only consonants but not vowels are written down. The resulting ambiguities (e.g. 'hs' for 'house' and 'his') have to be resolved by a second rule. However, orthographic transcription rules turned out to be rather complicated – at least in English. Therefore, systems like C-Print are often based on a set of rules which are in turn based on a phonetic transcription of the spoken words. On the basis of a set of shortening rules, the note taking person does not write certain graphemes but phonemes of the spoken words.

Summary of CAN-systems:

CAN-systems can be used for real-time speech-to-text conversion if a message-to-message transfer is sufficient. For word-for-word transfers, the typing speed of CAN-systems is not high enough.

The quality and speed of the transfer depends on the kind and quality of the dictionary which translates abbreviations or shortened words into the corresponding readable long forms. To use a CAN-system, the note taking person needs to learn either the abbreviations of the short-to-long dictionary or the rules of short-phoneme/grapheme-to-long-grapheme conversion the dictionary is based on.

Linguistic knowledge is necessary for adaptations of the wording.

3.3 Communication access real-time translation (CART)

Communication access real-time translation (CART) uses stenography in combination with a computer based dictionary. The phonemes of a word are typed on a steno keyboard which allows the coding of more than one phoneme at a time. It is thus possible to code e.g. one syllable by a simultaneous key press with up to all 10 fingers: The left keys on the keyboard are used to code the initial sound of the syllable, the down keys code the middle sound and the right keys of the keyboard code the final sound of the syllable. For high frequency words or phrases, prefixes and suffixes, abbreviations are used.

The phonetic code of the words or the respective abbreviation is immediately translated into the corresponding long form by a sophisticated dictionary. An example (taken from www.stenocom.de, cf. Seyring 2005) can illustrate the advantage with respect to typing speed:

a) typing on a normal keyboard: 88 strokes

Ladies and Gentlemen! The people want to have calculability and stability.

b) Same words in machine steno code: 12 strokes

(The code between two spaces is 1 stroke, typed with up to 10 fingers.)

*HRAEUPLBG STPH T PAOEPL WAPBT TO*F KAL KUL BLT APBD STABLT FPLT*

The parallel typing with CART systems results in a high typing speed which is sufficient for word-for-word transcripts in real-time. The phonetic transcription reduces ambiguities between words and allows real-time accuracy levels of more than 95%. Moreover, if the audience is not interested in word-for-word conversion, CART systems can also be used for message-to-message transfers since they allow adaptations of the wording in real-time.

CART-systems can be used in silent or noisy surroundings, their efficiency mainly relies on the education of the person who does the writing. However, the education of the speech-to-text provider is one of the most limiting factors of CART systems. 3-4 years of intensive education with a lot of practicing are the minimum for a person to become a CART speech-to-text provider who produces text in sufficient quality (less then 4% of errors) and speed (ca. 150 words per minute). The second limitation of CART is the costs for the steno system of around 10.000 Euro.

Summary of CART-systems:

CART systems are highly flexible tools for real-time speech-to-text conversion. They can be used in noisy or silent surroundings for word-for-word as well as for message-to-message transfer. The limitations of CART are located outside of the system, i.e.

- the long period of training which is needed to become a good CART provider
- the costs of the steno system

3.4 Comparison of Speech Recognition, CAN- and CART-systems

	Speech Recognition with re-speaking	**Computer-Assisted Note-taking**	**Communication Access Real-time Translation**
Exact word protocols	Yes	almost, but needs a lot of training and a sophisticated dictionary	Yes
Language adaptations	Possible with re-speaking	Yes	Yes
Education to use the method	Some hours for initial training of SR-system	some weeks- months	3-4 years
Special conditions	Minimum background noise	None	None
Cost of equipment[1]	100-200 € SR-system 50-100 € good microphone (opt.) 1.000 Euro notebook	1.000 € notebook (+ licence for the dictionary)	~ 10.000 € steno machine 1.000 € notebook (+ licence for the steno-longhand dictionary)

Table 1: Speech recognition, computer-assisted note-taking and communication access real-time translation in comparison.

4 Text adaptation

Spoken and written forms of language rely on different mechanisms to transfer messages. Speech for instance is less grammatical and less chunked than text. A real-time speech-to-text conversion - even if it is a word-for-word service - has to chunk the continuous stream of spoken words into sentences and phrases with respect to punctuation and paragraphs in order for the text to be comprehensible. A correction of grammatical slips might be necessary, too, for word-for-word conversions and even more corrections my be necessary for an audience with less language proficiency. While intonation may alleviate incongruencies in spoken language, congruency errors easily cause misinterpretation in reading.

The transfer from spoken into written language patterns is only one method of text adaptation. As discussed earlier, the speech-to-text provider might also be asked to adapt the written text to the language proficiency of the audience. Here, the challenge of word-for-word transfer shifts to the challenge of message transfer with a reduced set of language material. A less skilled audience might be overstrained especially with complex syntactical structures and low frequent words and phrases. The speech-to-text provider therefore needs to know whether a word or phrase can be well understood or should better be exchanged with some more frequent equivalents. S/he also has to know how to split long and complex sentences into simpler structures to make them easier to understand.

The know how of text adaptation with respect to the needs of the audience is highly language- and field-specific. People who become C-Print captionists learn to use text condensing strategies which is mainly aimed at reducing key strokes (RIT 2005) but might also reduce grammatical complexity and lexical problems. However, a recent study on the effects of summarizing texts for subtitling revealed that "summarizing affects coherence relations, making them less explicit and altering the implied meaning" (Schilperoord et al. 2005, p.1). Further research has to show whether and how spoken language can be condensed in real-time without affecting semantic and pragmatic information.

For German, it has already been shown that test questions can (offline) be adapted linguistically without affecting the content of the question. That is, many words and structures can be replaced by equivalents that are easier to understand (cf. Cremer 1996; Schulte 1993; Wagner et al. 2004). Further research will have to show whether this kind of text adaptation on word-, sentence- and text level (in German called "Textoptimierung") can also be realized in real-time.

5 Presentation format

The last challenge of real-time speech-to-text transfer is the presentation of the text on the screen in a way that reading is optimally supported. The need to think about the presentation format is given as the text on the screen is moving which is a problem for the reading process. We usually read a fixed text, and our eyes are trained to move in saccades (rapid eye movements) on the basis of a kind of preview calculation with respect to the next words (cf. Sereno et al. 1998). But in real-time speech-to-text systems, the text appears consecutively on the screen and new text replaces older text when the screen is filled. A word-by-word presentation as a consequence of word-for-word transcription could result in less precise saccades which subsequently decreases the reading speed. Reading might be less hampered by a presentation line-by-line, as it is e.g. used in C-Print (cf. the online presentation at http://www.rit.edu/~techsym/detail.html#T11C). However, for slower readers, also line-by-line presentation might be problematic since the whole "old" text is moving upwards whenever a new line is presented. As a consequence, the word which was actually fixated by the eyes moves out of the fovea and becomes unreadable. The eyes have to look for the word and restart reading it.

The optimal presentation of real-time text for as many potential readers as possible is an issue which is worth further research, not only from the perspective of real-time transcription but also for subtitling purposes.

6 Perspectives

Real-time speech-to-text transfer is already a powerful tool which provides people with a hearing impairment access to oral communication. However, elaborated dictionaries as they are needed for efficient CAN- or CART-systems are not yet developed for many languages. Without those dictionaries, the systems can not be used.

Linguistic research has to find easy but efficient strategies for the real-time adaptation of the wording in order to make a message understandable also for an audience with limited language proficiency.

Finally, the optimal presentation of moving text to an audience with diverging reading abilities is a fascinating research field not only for real-time speech-to-text services but with respect to the presentation of movable text in general.

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Using Networked Multimedia to Improve Academic Access for Deaf and Hard of Hearing Students

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Abstract

Deaf and hard of hearing students experience barriers that make access to mainstream universities a challenge. Educational technology has the potential to better include these students in the academic mainstream. This paper begins by outlining historical trends in education for deaf students because understanding the unique characteristics and experiences of members of the deaf community will be crucial for successful design. We then discuss current trends in educational technology in general, especially those that will ultimately be made accessible or compatible with the needs of deaf students. Finally, this paper describes the author's proposed thesis work: the development and evaluation of a classroom platform for deaf and hard of hearing students to access remote interpreters and captionists, avoid visual dispersion, and facilitate classroom interaction.

1. Introduction

Entering mainstream universities involves extra challenges for people who are deaf and hard of hearing: skilled sign language interpreters and captioners with advanced domain knowledge can be difficult to find; multiple visual channels of information in the classroom can be difficult to juggle; and collaboration inside and outside the classroom is often strained due to language barriers [28].

Classroom technology research aims to improve educational experiences for all students and this creates opportunities to better include deaf and hard of hearing students. Wireless networks, data projectors, and portable computing devices can be used to bring in remote interpreters, support the sharing and capture of instructional materials, and provide additional communication channels for everyone. A more digital academic environment creates an opportunity for customization to better suit the needs of individual students.

2. Goals and Contribution

This research will investigate and develop technology to help manage the many academic tasks required of the estimated 20,000 deaf and hard of hearing students at mainstream universities in the U.S. [38]. Development will parallel other educational technologies so that technology for deaf students will be similar to those used by all students. The DHH Cyber Community project at the University of Washington will be a catalyst bringing together video remote interpreter services, remote captionists, skilled interpreters, and knowledgeable people within the deaf community. The proposed work will utilize this web of resources and services and the high-bandwidth connections between them to promote the best educational environment and lower barriers to participation in university-level academics for deaf and hard of hearing students regardless of classroom type, instructor accommodation, or locally available resources.

3. Background

When designing for deaf and hard of hearing people, it is important to understand that as a group, they have extremely varied backgrounds and educational experiences. A person's self-identification as either deaf, hard of hearing, or hearing impaired is often primarily a personal choice and not a function of the degree and onset of hearing loss. Deaf people tend to prefer sign language, often choose not use their voice, and are likely to be involved in the signing Deaf Community (note the capital "D" indicating a sense of pride in the uniqueness of sign language and culture). Hard of hearing people tend to speak and lip-read and may rely on residual hearing, hearing aids, or cochlear implants when communicating with hearing people. They may also know sign language and participate in the Deaf Community. These groups are by no means distinct and both people and preferences can shift across group lines. Alternately, elderly people who have lost hearing later in life may better fit into a third group as they are unlikely to know sign language, do not identify with Deaf Culture, and may prefer the term hearing impaired (which is a term typically rejected by members of the Deaf Community as it is thought to negatively emphasize a deficiency).

The degree of a person's hearing loss is only a small aspect of their disability and does not necessarily determine the best classroom accessibility solution or accommodation. For some people, the ability to adjust the audio volume may be sufficient. For others, translation to a signed language may be more appropriate. For others still, access to text alternatives may be the best solution. For those who were raised in environments promoting speech training, good access to the face of the speaker may be sufficient. These different preferences are in large part due to varied backgrounds and personal experiences and no type of accommodation is perfect. Understanding the diversity of experiences from early childhood on is an important aspect of designing with and for deaf and hard of hearing students.

3.1. Issues Affecting Deaf and Hard of Hearing Students

From a strictly audiological point of view there are several ways to quantify hearing loss. The most common metric is the degree of loss in decibels (dB) from mild loss (25 to 40 dB) to profound loss (90 dB or greater). But, as the next sections will illustrate, hearing loss itself is only one of many factors affecting language acquisition and education of deaf students.

3.1.1. From Infancy to Early Childhood

There is a distinction between pre- and post-lingual deafness, meaning that deafness occurred before spoken language acquisition or after, respectively. Oral training (learning to speak and read lips) is much easier for post-lingually deaf children and much more difficult and often unsuccessful for pre-lingually deaf children. In either case, excellence at lip reading is not common.

Language acquisition depends much more strongly on early exposure to language, whether spoken or signed; relying on lip reading alone very much restricts the child's language exposure. In fact, deaf children born to deaf parents (much like hearing children born to hearing parents) experience almost effortless natural language acquisition simply through exposure to the language of their parents. However, ninety percent of deaf and hard of hearing children are born to hearing parents who do not know sign language. Many of these children are not exposed to any language in a natural way during those early critical years of language acquisition. Oral training is not a substitute for the almost effortless language acquisition that occurs naturally. This lack of early exposure to any language may be the reason that many deaf people struggle with the written form of spoken languages, for example English. In fact, for the lucky ten percent, early exposure to sign language and strong signing skills seem to act as a linguistic bridge to more easily acquiring English as a second language [31]. The effects of language acquisition during the early childhood years trickle through grade school, on to high school, and ultimately affect access to college and career.

3.1.2. From Early Childhood through Grade School

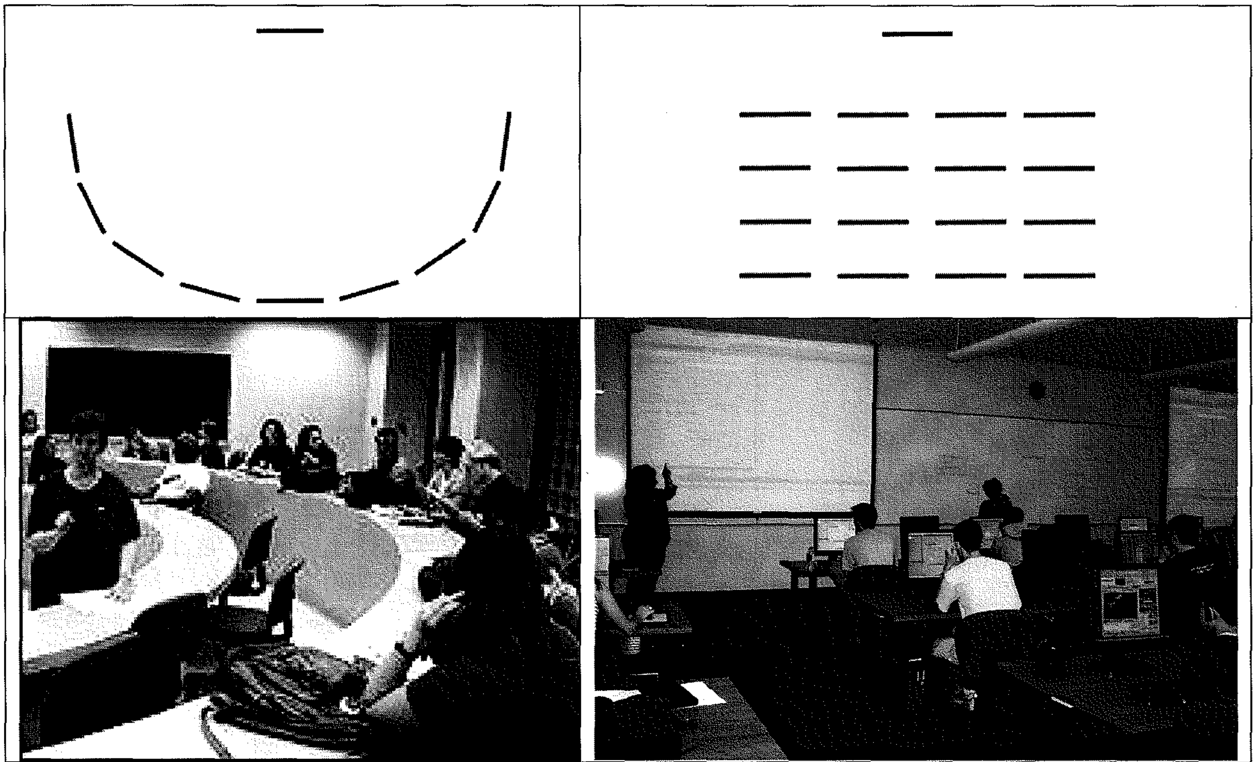
The type of schooling environment that a deaf student experiences growing up will also affect their preferred accommodation and access to the college classroom. Education for deaf children in the U.S. has undergone policy changes that have resulted in even more diversity within the deaf and hard of hearing group.

Until 1975, education of deaf children and adults in the United States was very centralized. Residential schools for the deaf were introduced in most states during the 1800s and Gallaudet University (an all-deaf liberal arts university) was founded in 1864. Centralization is based on the concept that deaf students need a specialized education because of their disability. In 1975 there was a fundamental change in public policy concerning the education of deaf people and others with disabilities with the passage of Public Law 94-142 now called the Individuals with Disabilities Education ACT (IDEA). The law mandated that all children with disabilities are assured a free appropriate public education. This "full inclusion movement" has not been without controversy [22]; some assert that a mainstream classroom may not be an ideal learning environment as it isolates students and reduces exposure to the deaf community and deaf role models. Since then, the percentage of deaf students attending residential schools has declined steadily to about 15% [45], with the majority attending mainstream schools.

3.1.3. From High School to College and Beyond

Although a large segment of deaf and hard of hearing students attend the three major universities serving primarily deaf students (Gallaudet, National Technical Institute for the Deaf (NTID), California State University Northridge (CSUN)), the vast majority of deaf students attend mainstream colleges and universities. According to the National Center for Education Statistics (NCES), over 20,000 deaf and hard of hearing students are enrolled in post-secondary educational institutions in the U.S., approximately 93% at the undergraduate level. This is likely an underestimate as the survey was conducted more than a decade ago, it did not include primarily deaf universities like Gallaudet, NTID, and CSUN, and not all students identify themselves to the university as deaf or hard of hearing. Over 50% of 2- and 4-year post-secondary institutes in the U.S. have identified as serving 1 or more deaf or hard of hearing student, nearly 95% for larger colleges and universities [38]. This illustrates how deaf and hard of hearing students are spread thinly at universities across the country, a point we will come back to later.

There are striking differences between classrooms geared toward all-deaf classes versus typical mainstream classrooms. All-deaf classrooms tend to be aligned in a semicircle so that all students can easily see the instructor, presentation, and all other students. Mainstream classrooms may have a number of different configurations, but the most frequent is rows of students all facing the front of the class (see Figure 1). Clearly, mainstream classrooms were not designed with the deaf student in mind.



a) Deaf Classroom at Gallaudet University (www.npr.org "At Gallaudet, a Turn Inward Opens New Worlds")

b) Mainstream Classroom at Rochester Institute of Technology 9/2007 (interpreter far left, instructor front and center)

Figure 1: Deaf Classrooms as in a) focus on visual accessibility. Mainstream Classrooms as in b) are often arranged in rows.

Recent years have seen an increase in deaf and hard of hearing students attending mainstream universities, which is likely a result of the "full inclusion" movement, IDEA act, the Americans with Disabilities Act of 1990 that prohibits discrimination based on disability.

3.2. *Existing Accommodations*

This increase in deaf and hard of hearing students in the academic mainstream has resulted in an array of accommodations in academic settings including: interpreters, real-time captioners, hearing aids, FM systems, and note takers.

3.2.1. Interpreters

As more deaf students enter mainstream universities, there is a growing need for skilled sign language interpreters that have specialized, university-level knowledge and signing skills. Because deaf students are spread thinly across U.S. universities, matching a student interested in a given domain with an appropriate interpreter who has knowledge of that domain can be a challenge, especially for advanced courses and for universities serving only a small number of deaf students.

Video remote interpreting (VRI) has been used in the classroom to help increase resource opportunities for this matching problem. VRI uses an intermediary interpreter, not in the same room, who signs what is voiced and voices what is signed for deaf and hearing people from the within same room. Video relay services (VRS) have similar services and are very popular, but these services are restricted to telephone conversations between parties not physically co-located.

3.2.2. Real-time captioners

Communication Access Real-time Translation (CART) is the system used by court stenographers and closed captioners in both academic and non-academic settings to manually convert speech to text using a keyboard or stenographic machine.

Much like interpreters, real-time captioners can only effectively convey classroom content if they understand that content themselves. Thus, matching students with appropriate and knowledgeable captionists can also be a challenge. Remote CART can also be used where the operator receives the voice through a telephone or computer connection and the text is sent back over a data connection. Some CART systems allow the student to highlight and add their own comments to the real-time text as it scrolls across the computer monitor [41]. C-Print is a type of CART developed at the National Technical Institute for the Deaf that enables operators who are trained in academic situations to consolidate and better organize the text with the goal of creating an end result more like class notes and more conducive to study [17].

Several researchers are working on speech recognition for automatically displaying spoken language in text [5]. Error rates are slowly improving, but these systems have a long way to go until they are usable. Very low errors would be required as even the smallest error (imagine recognizing a "ought" when the speaker actually said "not") can completely change the meaning of the text. Using textbooks to train the system on relevant course content [27] can improve error rates. When these systems are used in the classroom, a human operator typically corrects the errors on-the-fly [49] and formats the text to show pauses to indicate speaker changes and to better facilitate later study. At this stage, the operator can not be eliminated altogether.

3.2.3. Note-takers

Because deaf students rely so heavily on visual communication, looking down to take notes causes them to miss the information that is being signed or captioned. Therefore, deaf students often receive notes from hearing students who volunteer (or sometime are employed by the university) to share their notes. Instructors may also copy class notes, slides, or transparencies for deaf students. While this helps ease visual burdens during class, the student may miss out on the value of taking and studying personal notes.

3.2.4. Accommodation of Choice

A student's choice of accommodation depends in large part on their experience and educational background: strength in sign language, comfort with English, and previous experience with a given accommodation. Studies that have compared different types of services (sign language instruction, sign language interpretation, CART, and C-Print) show mixed results, probably due to the diversity of student needs [32].

Additionally, the same student may choose different accommodations for different types of courses. As one student pointed out, real time text may be better than sign language interpretation for courses involving many new vocabulary terms: "C-Print works best in lecture-based courses and courses that rely more on words as opposed to formulas or graphics." [17]. Sign language may be better for courses such as geometry containing lots of spatial and relative information or for courses focused on discussion or debate if the student's preferred mode of communication is sign language.

Can too much accommodation be a bad thing? Mayer *et al.* showed that both real time text captioning and in-person sign language interpretation together resulted in greater loss of information than either one alone, perhaps due to visual overload [34]. In contrast, Marschark *et al.* found that having both sources of accommodation (but shown on the same computer screen) was beneficial [32]. Furthermore, students learned more from sign language during class but got more out of real time text notes for studying. This could indicate that more channels of information are in fact beneficial, but only if they are arranged in a way that reduces visual overload, a point we will come back to in Section 3.3.1.

3.3. Accessibility Goals and Design Criteria

In spite of the plethora of possible accommodations, attrition of deaf students at the university level is high. This is partly due to missed classroom information and underdeveloped study habits such as note taking, but it is also related to difficulty with social and cultural connections with other students [28]. Our work will address both missed information through visual dispersion and translation as well as issues with collaboration with other students.

3.3.1. Reducing Visual Dispersion

> "The ear tends to be lazy, craves the familiar, and is shocked by the unexpected; the eye, on the other hand, tends to be impatient, craves the novel and is bored by repetition." ~ W. H. Auden

Problem:
Unfortunately, there are several ways that a deaf student can miss classroom information. Because deaf students receive nearly all classroom information visually, they must juggle their visual attention between instructor, slides, interpreter and/or captioner, and personal notes or handouts. Due to this juggling, information can easily be missed. Even when best practices for classroom setup are followed such as reducing visual obstacles (having the student sit up front) and utilizing techniques to include deaf students, the visual juggling act still results in missed information [25].

Even if explicit information is carefully provided, inadequate access to subtler, implicit information may put students at a disadvantage. For example, both conscious and sub-conscious gestures used by instructors often contain task-relevant information that has been shown to be helpful to the learner in problem solving activities [19]. If deaf students' visual attention is focused on the interpreter or the captions, they may be missing out on this alternative mode of information. Having better visual access to the teacher and the ability to replay both the instructor's actions and the interpreter and/or captions later may further reduce missed content.

Visual distribution problems often found in the classroom are summarized nicely by the experiences of one profoundly deaf and profoundly influential researcher while enrolled in a workshop to learn a new statistical software package (from [31]):

> Superficially, the learning context seemed ideal: The lecturer was a sensitive individual who went to great lengths to ensure full access by deaf individuals participating in the workshop. He had a projection of his own computer display on a large screen behind him, and each participant had their own computer for hands-on activities. The sign language interpreters were the best that could be found: all experienced in interpreting under such conditions. The two deaf participants had strong backgrounds in the use of computers, research, and statistics. Yet, both quickly became lost, viewing the two days as a waste of time. What went wrong?
>
> Primarily the problem was one of multiple, visual tasks placing too many demands on the processing of information in the learning situation. While the hearing participants were able to look at their screens and listen to the presenter, the deaf participants had to look away from the interpreter to see the instructor's screen or to try a procedure on their own computer. Missing one sentence of the instructions was enough to slow down or even derail learning. Watching the interpreter made it difficult to catch each action of the presenter or the projected screen.

Key Challenges:
Consolidating visual content into one device may prevent missed information and reduce the visual juggling act. Laptops, tablets, webcams, and high bandwidth connections can all be used to consolidate and conglomerate the visually important

aspects of the classroom, making them easier to access. Regardless of the student's choice of accommodation and the source of that choice (whether the interpreter or captioner is physically present or remote) presenting it in one device along with the instructor, the presentation materials, personal annotations, and potentially other classmates will allow the student to make better use of their visual modality.

Consolidation will likely help since studies have shown that items located closer to a person's current visual task are more easily and accurately found than items located farther away in the periphery (the eccentricity effect). Wolfe *et al.* offer proof that visual attention is affected by eccentricity by showing that people are more likely to notice and quicker to locate nearer items. Also, the effects of eccentricity are reduced when there are fewer distractions on the screen [51]. We may be able to further reduce clutter by giving the user control over their interface to emphasize what is most important and cut out what is not, as in WinCuts [47].

A frequent question when talking about visual interfaces for deaf learners is if deafness has an effect on visual perception. While the visual modality is clearly important for deaf students, there is no evidence that deaf people are able to make better use of vision than hearing people [31]. However, in at least one study Corina *et al.* have shown that deaf students are better able to redirect attention from one spatial location to another and better able to detect important motion in their periphery [13]. This is especially impressive considering that deaf people watching sign language focus on the face of the signer over 95% of the time [10].

Empowering students to design their own layout and formatting on-the-fly will be important for supporting a diverse user group with diverse needs, but it may also offer insights into future user interface design for this group.

3.3.2. Broadening Opportunities for the Best Services

> "Teachers are the most important classroom 'technology' and students are the least utilized classroom 'resource.'"
> ~ Harold Johnson, Kent State University

Problem:
Deaf students can also miss information in the classroom if that information is not properly or accurately conveyed to them. Section 3.2.1 described the importance of matching students with interpreters and/or captioners who understand and can accurately interpret for advanced, university-level content. Because students are spread so thinly, finding appropriate interpreters and captionists can be a problem.

Key Challenges:
Using high-bandwidth connections and remote interpreters and captionists would increase the pool of available accommodation for a student to choose from. Several universities and companies including Viable Technologies [48] and HandsOn VRS [21] are already pooling their resources and offering services for this type of remote assistance in the classroom. This has been especially important in the recent past for remote schools and colleges that otherwise would not have the resources to offer this type of assistance [18]. Also, the Media Access Group at

WGBH provides real-time captions for live Web events and Web conferencing [35], which could be used for online courses. Remote accommodation has also been shown to be adequate for both real-time captioning and sign language interpreting as video-based interpreting appears to be just as effective as in-person interpreting [33]. Because the system will be flexible with students' choice of accommodation, they could potential choose an automatic speech recognition system, assuming error rates were tolerable and alternate accommodation was not available [40].

Better collaboration through the existing high-bandwidth connections between universities would allow better access to skilled interpreters familiar with specialized, university-level topics. The DHH Cyber Community project is already pooling together these types of resources. This approach will also allow different types of students to receive differing accommodations based on preference. For example, one student may prefer a remote sign language interpreter while another student prefers real-time captioning.

Relying on high-bandwidth connections may not always be an option and anytime a technology can use less bandwidth, it will be available more of the time. Our MobileASL group has developed compression techniques specific to sign language that may help reduce bandwidth usage [11]. Finally, the digital nature of videos will also have the benefit of being recorded, archived and perhaps distributed.

3.3.3. Reducing Barriers to Classroom Participation

"Tell me and I will forget;
show me and I may remember;
involve me and I will understand."
~ Chinese proverb

Problem:
Communication, and thus participation, in the classroom can be strained for deaf and hard of hearing students due to language barriers. Plus, events outside the classroom (project group meetings and impromptu study groups) where there is no scheduled interpreter can inadvertently exclude deaf or hard of hearing students.

By the time students reach college, they are a diverse group with diverse backgrounds, knowledge, and communication/accommodation preferences. Mainstreamed students who may not have sign language skills and/or knowledge of deaf culture can feel excluded from other deaf students and sometimes stereotyped by hearing students [26]. This may further increase barriers to participation, which is crucial to academic success. A study of multimedia learning environments found that nothing affected learning more than student participation [14]. The study tested text only, text and content movies, text and sign movies, text and discussion questions, and all of these together. The only conditions to significantly affect learning were the ones involving discussion questions. Clearly, students do not learn nearly as much if they do not participate and interact in their own learning.

Key Challenges:
Deaf students may benefit from technological environments that put more students on equal footing. In fact, Richardson *et al.* found that the effects of hearing loss on

participation in distance learning courses was slight, perhaps because the asynchronous textual modalities of communication lowered the barrier to participation [43]. New "digital" classroom environments may have a similar effect, opening up new possibilities for promoting equality *within* the classroom.

3.3.4. Enabling Instructor Participation (buy-in):

"Teachers open the door, but you must enter by yourself."
~ Chinese Proverb

Problem:
Instructors do not like to trouble shoot during class-time so the platform should work seamlessly with or without other technologies being used.

Key Challenges:
While the proposed technology will likely be beneficial for a wide range of classroom, meeting, study group, and other academic situations, we are primarily focusing on lecture-style classrooms for a number of reasons. First, enabling access to the most common type of pedagogy found in large university courses will make the biggest impact for deaf and hard of hearing students pursuing degrees at mainstream universities. Second, we feel that if we were to require a different type of pedagogy, use of the system would be reduced. Instructors should be able to teach in a way that is most effective for them and deaf students should be able to take any class they like, regardless of the teaching style or compliance of the instructor. Minimizing the burden on the instructor and placing more of the power and choice with the student will not only increase adoption of the technology, but will empower and increase opportunities for the student.

To summarize, people with hearing loss form a disability group very different from other disability groups. Accommodation needs can range from sign language interpretation to visual access to the speaker to text captions to FM systems and hearing aids. Clearly, a one-size-fits-all approach has a good chance of failure as different solutions will work for different students (perhaps even for different classes or situations) and flexibility and user choice will be key to adoption.

4. Related Work

Work related to the proposed technology can be divided into technology designed for typical mainstream audiences and technology designed specifically for deaf audiences, whether in the mainstream or deaf classroom.

4.1. Educational Technology (in general)

Classroom technology research aims to enhance educational experiences for all students by using technology to better engage and involve students in the classroom through active learning. Insights from this field will be incorporated into our project to better include deaf and hard of hearing students.

Electronic classroom response systems (CRSs) allow instructors to solicit feedback and results from student activities, and receive them electronically to then summarize or discuss as a class. These systems have been shown to have positive effects on classroom participation, active learning, and conceptual understanding [23]. They also tend to encourage shy or less outspoken students to contribute more and reduce the impact of students who tend to dominate classroom interaction [39]. "Clicker" systems are a subset of CRSs that allow students to submit short responses to the instructor (such as answers to multiple choice questions or numeric answers) so that the instructor can display summaries of class responses and opinions of students [12][16][20][44] or groups of students [15]. The summaries can serve as feedback on class understanding for the instructor and can spark conversation about a given topic, but they limit students in the type of their submissions and don't allow for anonymous, independent questions.

Systems that allow text and digital ink to be submitted to the instructor are less restrictive and better at promoting self-initiated dialog between students and instructor. The University of Washington's Classroom Presenter uses networked Tablet PCs to allow students to electronically submit work, questions, and/or comments to the instructor who can then choose to display submissions and digital ink on lecture slides [2][30]. Ubiquitous Presenter [50] and DyKnow [6] offer similar functionality, but with a web-based interface that requires no tablet (a laptop will do). In addition to submitting questions anonymously during class, ActiveClass allows students to rate the questions of other students to bring them to the attention of the instructor [42]. Because cost barriers exist to providing all students with similar technology, Classroom Presenter also offers a version using mobile phones, a device more and more students tend to already have [29].

The digital classroom has incredible potential to better accommodate the needs of students with disabilities in mainstream university classrooms. For example, LiveNotes uses digital ink over lecture slides to encourage group conversations and cooperative note-taking during lectures [24]. This type of interaction may allow deaf students to become more involved in the note-taking process without being solely responsible for their own notes.

As academic environments become more digital, capture and retrieval introduce interesting areas to improve content accessibility. Synchronization of video feeds, digital ink, and presentation materials could result in better preservation and easier post-class access, much like eClass [8] and other classroom capture techniques [37]. One might think that classroom capture would encourage students to skip class but studies suggest that it does not. In fact, in one instance students were more likely to attend if the class was being captured. Students tend to recognize the value of interactions that occur in an in-person group class [8], which helps to relieve the worry of missing class. As deaf students juggle their visual attention during class time, the ability to re-watch parts of the class that were missed may level the playing field and ease information retention.

4.2. Educational Technology for Deaf and Hard of Hearing

Both educational technology for deaf and hard of hearing students and educational technology for a general audience are developed to encourage participation and active learning. The focus of the former is typically more on translation of speech, new interaction techniques, and eliminating visual overload.

Networking within the classroom is also utilized in educational technology for deaf and hard of hearing classrooms. Linda Burik at NTID has shown active learning benefits from using wireless laptops and a SMART board in the classroom [9]. In her system, the teacher can show the students' work on the big class display for discussion, somewhat like Classroom Presenter but the instructor can "grab" student screens rather than receiving students "submissions." Students keep both their own digital work and digital copies of the instructor's notes so that participation in class and note-taking activities are one in the same.

Researchers such as Donald Beil have recognized the potential of using tablets in class to enable deaf students to take notes on top of, instead of away from, other classroom content [4]. Digital pen-based environments create further opportunities for deaf students in terms of self-notetaking as was proposed by Miller *et al.* using transparent video and overlaid digital ink to reduce the visual distance from the interpreter (video) and the student's notes (digital ink) [31].

In online distance learning settings, high-bandwidth connections and streaming video are already being used to better include deaf and hard of hearing students [7]. While this use of the technology works well for distance learning, we predict that the same benefits of inclusion will occur in the physical classroom as well.

To facilitate communication between deaf and hearing students in his classes, Jonathan Schull proposed a system that he successfully uses at RIT/NTID for students to join a common, on-the-fly chat room and display text concurrently to best augment a face-to-face conversation.

4.3. Enabling Technology (a comparison)

ConferenceXP [3] and Adobe Connect [1] are two conferencing technologies that have potential for use in our work. Both enable video/audio conferencing and remote sharing of presentation slides, application windows, and even entire desktops. We will leverage their existence and stability as a foundation for our own work.

ConferenceXP, developed at Microsoft Research, provides the infrastructure for networking the Tablet PCs used in Classroom Presenter and is also used for audio and video distance learning and classroom capture. Classroom Presenter is currently used by at least 70 instructors at universities nationwide and this number is likely to grow in the future, so compatibility would ensure that the technology used by deaf and hard of hearing students will work well in conjunction with the classroom technology used by all students.

Adobe's Connect also offers video and presentation conferencing technology that could serve as a backbone for remote connections with interpreters and captioners and sharing of in-class resources [1]. In fact, Adobe currently has an alliance with Caption Colorado (www.CaptionColorado.com) and WGBH (www.wgbh.org) to provide captions for meetings. Several universities in the U.S. are currently using Connect for remote, online distance learning. Its use as a distance-learning tool ensures that several of the components needed for in-class involvement and participation will be available.

Both ConferenceXP and Connect have released open source versions of their systems that would allow us to make the necessary enhancements needed by deaf and hard of hearing students, discussed in Section 5.

We will also leverage the high-bandwidth, reliable internet connections that exist between universities enabled through Internet2 and Cyber-infrastructure communities to provide the best quality video/audio and stable transmission.

Describing our planned use of these systems is best illustrated with a scenario. The following three scenarios are intended to convey different types of students, accommodation needs, class structures, and enabling technologies.

4.3.1. Scenario A (Connect, Remote Interpreter)

Sally is a deaf student at the University of Io. She is fourth-generation deaf and prefers to converse in American Sign Language. She is majoring in Psychology and taking Child Psychology 101. The class is discussion-based; the instructor tends to show slides and videos and then expects students to discuss their opinions about them. For this class, Sally is using Adobe Connect to bring in a remote interpreter from a different university who happens to hold a degree in Child Psychology.

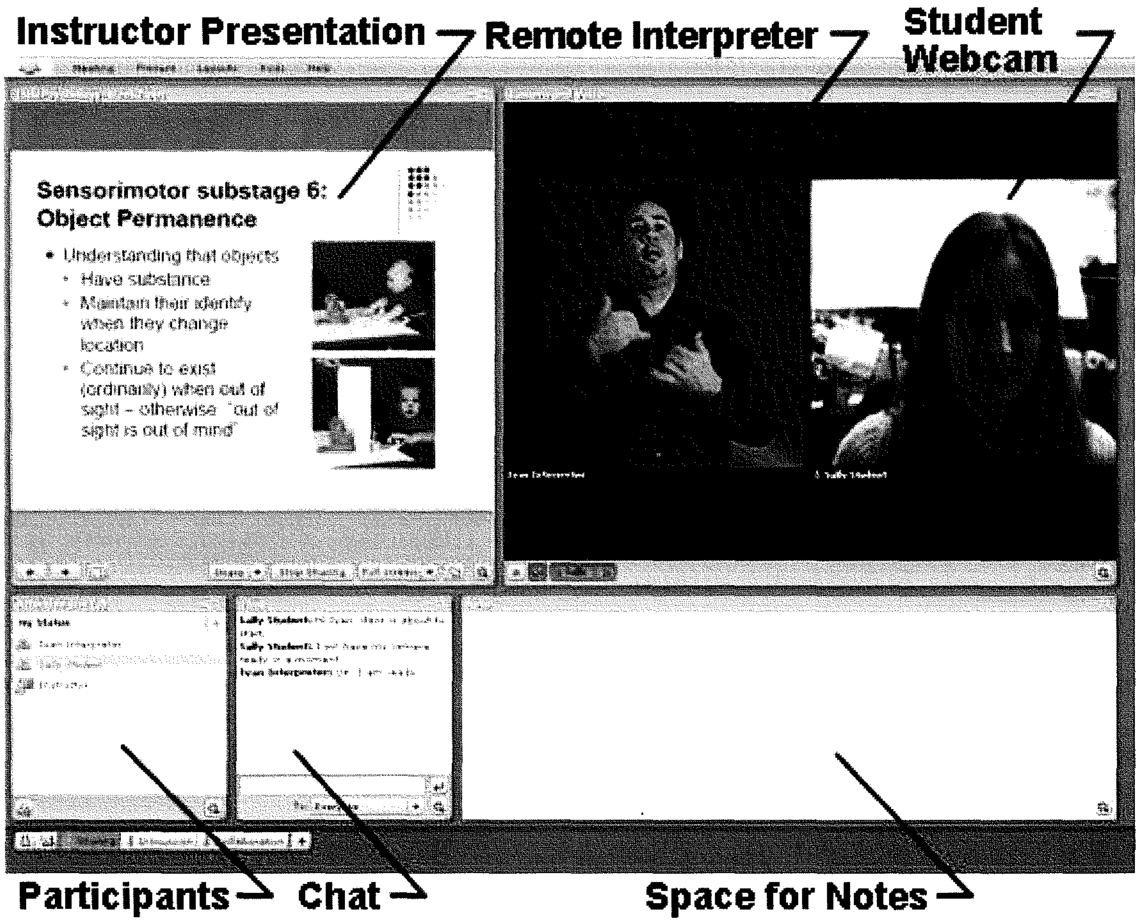


Figure 2: Using Adobe's Connect in Scenario A. Sally's computer screen show's the instructor's presentation, her remote sign language interpreter,

her own webcam, and the ability to chat and take notes.
The instructor has agreed to upload his slides and videos before classes start and to use the system during class. Because he only uses the power-point feature to show slides and videos, it is nearly the same process he would have used to teach (in fact he is even using the same materials as last quarter). The only noticeable different in class is that he now wears a microphone and earpiece to transmit voice between him and the interpreter. The students pass a microphone around during discussion and the instructor appreciates this added structure and enforced turn-taking.

Figure 2 shows Sally's screen on her laptop at the beginning of class. She has access to the instructor's slides and videos which are synchronized with his presentation. She can see both her interpreter and herself. She can chat with the interpreter and the instructor (if he checks the chat log) for example, incase the video stops working. And she has space to take typed notes. If she has a question or takes a turn in discussion, she signs to the interpreter who then voices for her. For this class, she chooses to turn the volume up on her laptop because the class is small and everyone can hear the interpreter. For larger classes, she would have the instructor repeat what he or she hears in their earpiece.

4.3.2. Scenario B (Classroom Presenter, Remote Captionist)

Bobby is a hard of hearing student at the University of Ganymede. He is majoring in Computer Science and currently taking Data Structures. He has only recently learned sign language (since he started college), so he does not yet feel comfortable with an interpreter. He prefers to use his voice to communicate and uses real-time captions during class because there are so many different vocabulary terms and acronyms in Computer Science courses and seeing the words helps him to find the topics later. He uses a note-taker because, in addition to the captions, he must watch the instructor who often writes code on the screen. Bobby has chosen ConferenceXP as a way to connect with his favorite captionist who is also a computer geek and so understands the content and is occasionally creative with ASCII art.

Luckily, his Data Structures instructor this quarter is using Classroom Presenter, so it will be easy for him to link the ConferenceXP connection he needs. All the students in class have TablePCs and submit in-class activities with digital ink. He too can create submissions and this puts him on the same level as other students. The use of tablets also gives him direct access to the notes of his note-taker. This enables him to add to the notes if he wants, but it mainly helps him refer back to the notes later because he sees them as they are created. The appearance of his screen can be seen in Figure 3.

From the instructor's perspective, her teaching process is exactly the same. She simply wears a microphone for the captionist and tells Bobby which session to connect to so that his tablet is on the same network as all the other tablets. Bobby then gives this information to his captionist, so that he too can see the slides. Instead of walking around the room with a microphone, the instructor prefers to repeat questions asked by hearing students as she feels this is a good practice to make sure all the other students heard the question.

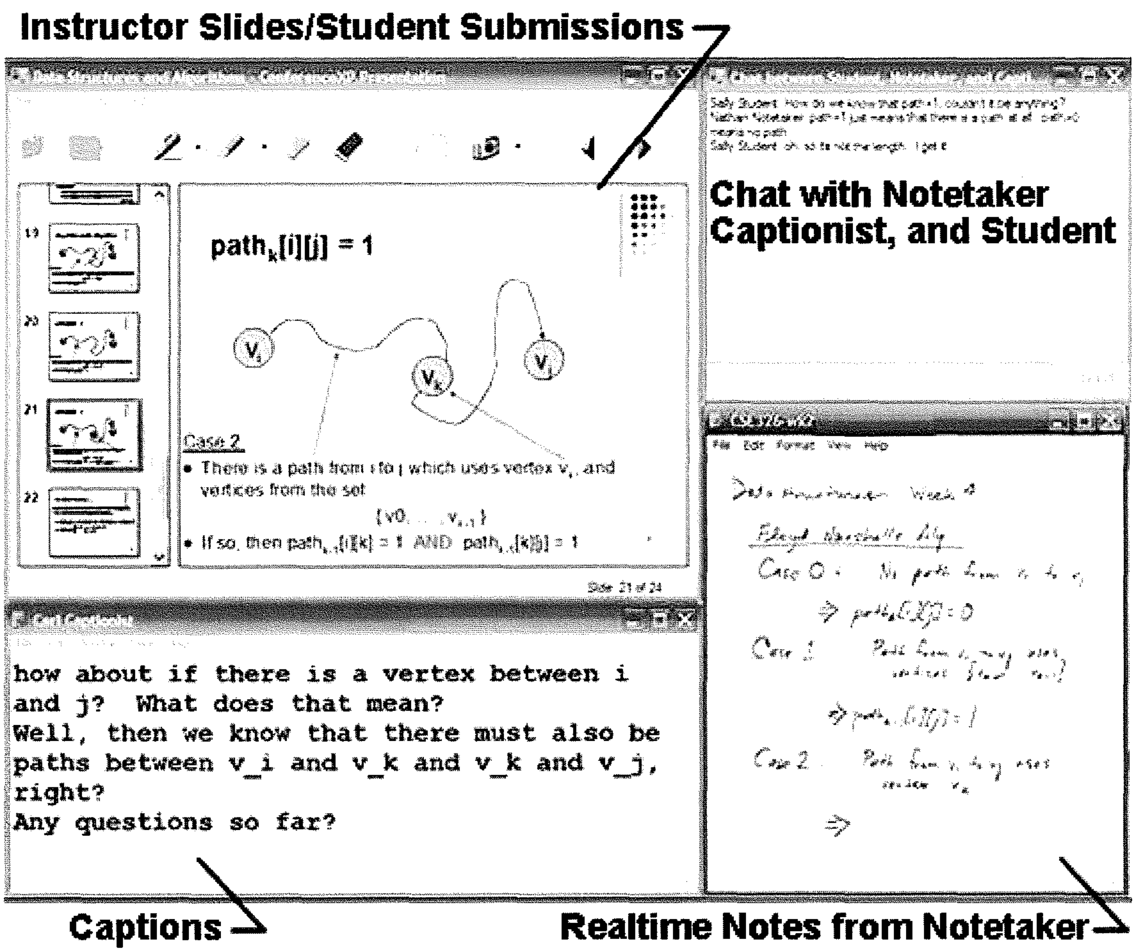


Figure 3: Using ConferenceXP in Scenario B. Bobby has the same level of involvement as all other students as they all submit activities with digital ink. He has access to a remote captioner and the digital notes created by his note-taker in class. He can chat with both his captioner and note-taker.

4.3.3. Scenario C (Interpreter in Class, Either Technology)

Tom is a deaf student at the University of Callisto and has attended mainstream schools from Kindergarten through high school. He prefers sign language interpreters and is accustomed to using them in class. This quarter, he is taking Intro to Biology in a huge, stadium-seating classroom. Even if he sits at the front of the class, the projected presentation is so large that he feels as though he is watching a tennis match between the screen, the instructor, and his interpreter. Instead, he sits a few rows back and uses a webcam to capture the entire front of the class. Then, he cuts out the important pieces: the instructor, presentation, and interpreter. He arranges these components on his screen so that he still has room for a chat window with a friend in class and a section for his own notes. Because the interpreter is present in the class with him, he can easily raise his hand, ask questions and interact.

5. Thesis Proposal

Existing technology has potential to alleviate some of barriers to and encourage participation in mainstream university-level academics for deaf and hard of hearing students. Designing, implementing, and evaluating technological solutions that bring many different technical and human resources into the classroom in an accessible and unobtrusive way is a challenging research problem. Technology has been shown to enhance education in the classroom and these "digital" environments open up new possibilities for leveling the academic playing field for deaf and hard of hearing students.

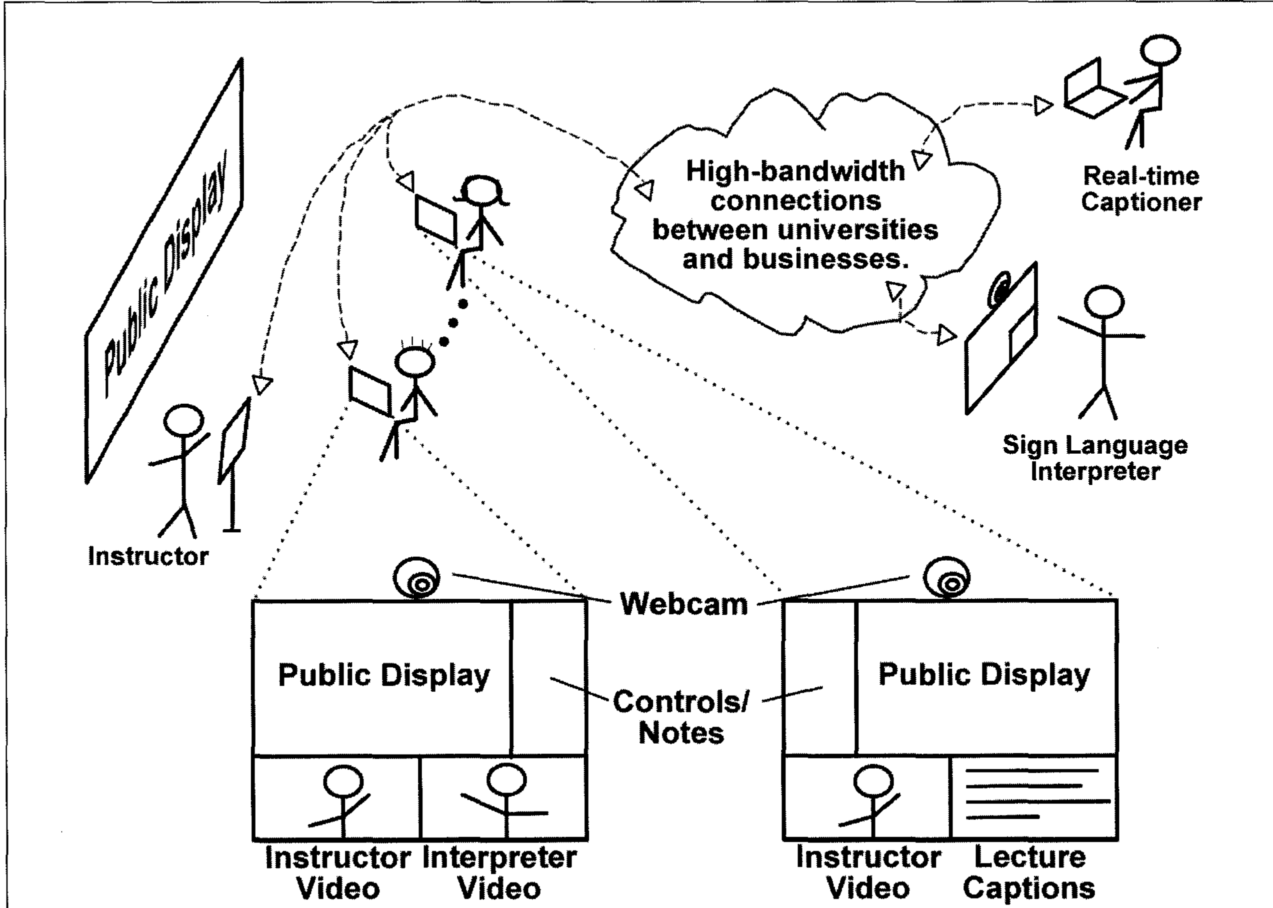


Figure 4: Networked multimedia brings remote interpreters and captioners into the classroom. Students have access to presentation, instructor, accommodation of choice, and their own notes. The instructor uses a microphone and earpiece and to relays audio, video, and presentation materials to the remote interpreter. Students' webcams relay questions and discussions through the interpreter to the rest of the class.

We will investigate effective ways for leveraging collaboration technologies for enhancing the participation of deaf and hard of hearing students in academic settings. The University of Washington's Classroom Presenter [2], Conference XP [3], and Adobe's Connect [1] will serve as a backbone so that technology for deaf students will be similar to and compatible with future classroom technology for all students. This technology will also be used to bridge the cultural and language gap between hearing and deaf students and encourage group work using text and digital ink. Given the scenario where all students are equipped with a networked Tablet PC, an additional opportunity exists for student collaboration. Finally, capture and retrieval introduce interesting areas to improve content accessibility. Synchronization of video feeds, digital ink, and presentation materials could result in better preservation and easier post-class access.

5.1. Enabling User Control of the Interface

Different accommodations will be required for different students, different classroom situations, and various aspects of the classroom will be more or less visually important for different students at different times. Flexibility in the interface will be crucial for success. We will modify existing video conferencing and classroom technology to enable students to choose the size and visual importance of each interface component. Using techniques like those found in WinCuts [47] and Facetop Tablet [36], our interface will allow students to crop, zoom, show, hide, and arrange independently, all while maintaining compatibility with technology used by other students and the instructor. To help reduce clutter on the screen, students may choose levels of transparency for videos feeds and other desktop components so that overlap can occur when appropriate. Imagine an interpreter standing to the left of a public display. She occasionally references specific items from the display as the instructor is talking about them. The student may want to reduce his video feed of the interpreter to show only her signing box (upper body from waist to the top of her head) and it will be important that her video feed appears to the left of the video feed showing the public display. No interface could be expected to predict these types of scenarios and students preferences. The best solution will be to engage the student in the creation of their own academic environment in a way that adds minimal complexity to the interface.

5.2. Enabling Collaboration and Group Work

Communication, participation, and active learning in the classroom have all been shown to promote learning in positive ways. These types of activities can be difficult for deaf students due to language barrier and interpreter/captioner delay. Compatibility with other classroom technologies, such as Classroom Presenter, will assist with this. The ability to anonymously submit questions and answers to the instructor is likely to play a role in reducing barriers to participation.

Additionally, we will develop mechanisms to create or access alternate channels of communication if they are available. If students in the classroom have digital-ink-based devices, students will be able to share notes much like LiveNotes [24]. Students will be able to connect to synchronous text chat channels for discussion much like in the classrooms of Schull [46]. If the deaf student has arranged to have a note-taker, the two could combine efforts by having access to the digital ink or text notes being created on-the-fly.

5.3. Enabling Capture and Later Retrieval

Because deaf students have a multitude of priorities that divide their visual attention during class, having access to a captured version of that class for review may help them to fill in missed content and parse class notes.

We will create an online repository for classroom capture if the student chooses this option. Mechanisms for both student and instructor security will be explored. We will borrow some of the tried and true techniques from eClass [8] for implementing segmentation of the recordings. For example, slide changes are a natural way to segment the video and allow students to easily access the interval of the class they are interested in. We will also explore techniques for allowing students to mark their own points of interest for later retrieval during class.

5.4. Evaluation Techniques

Evaluation of the proposed classroom technology will be an integral aspect of the project from day one. Involvement from the deaf and hard of hearing community is key to adoption, so evaluation will take the form of focus groups, participatory design techniques, and iterative design where feedback from students is incorporated into the design at every iteration.

However, implementing traditional HCI techniques of evaluation will be difficult due to a limited number of diverse users, inconsistencies in instructors' teaching style, and technology and classroom setup. Doing studies with sustained use over several courses and several students will be impractical. For example, it would be difficult to teach the same course with and without the proposed technology because comparisons may not easily be made across a small handful of students.

Some of the most successful and influential work in the field of educational technology has studied the effects of learning, scores, participation, and student responses to questionnaires and interviews across hundreds of students and tens of years [8][24]. Interestingly, none of the studies were able to find significant results from the collections of attendance and grades (two data points that would be difficult for us to use reliably). Even 33 years of research on electronic response systems yields inconclusive results on effects of academic success, citing pedagogical practices of the instructor among other things as dominating factors [23]. The most significant and meaningful results from these studies were obtained through student questionnaires, surveys, and observations of student behavior.

Student surveys, focus groups, student and instructor artifacts, observational interviews with both instructors and students that focus on student perceived benefits seem to be the norm [6][15][20][30]. Learning improvements, test scores, and grades may not be reliable measures because evaluations "in the wild" in actual classrooms will have too many confounding factors, including variability of students, instructor's teaching style and level of engagement, participation of other students in the class, time of day, and lecture topic. Cost/*benefit* analyses may be more practical than cost/*effective* analyses and may even result in better indicators of quality of learning and interaction with instructors and peers. Thus, we will measure impacts on classroom environment, participation rates, and subjective measures based on student perceptions.

Evaluations for the project will test the following hypotheses.
Potential Hypotheses:

1. Students will feel that using the technology in class makes lectures more engaging.
2. Students will feel they have learned more as a result of using the technology.
3. Students will participate more in classrooms when using the technology.
4. Students will feel they participate more as a result of using the technology in the classroom.
5. Students will feel that the quality of their interaction in the classrooms is improved when using the technology.
6. Some students will alter their seating behavior as they are no longer forced to sit at the front of the class.
7. Students will view the technology as a useful study tool.
8. A majority of students will voluntarily continue to use the technology after participating in the study.

In addition to these hypotheses, we will also include evaluations for some of the adverse effects that we hope to avoid or outweigh with our technology, including 1) a learning curve for the technology that distracts from learning course content, 2) in-class distractions caused by the technology, 3) increased potential for off-topic behavior. Although we should decide carefully if any effects from point 3) are in fact adverse. In light of research that suggests that attrition of deaf students is partly due to isolation, increases in communication, even if off-topic, may have more of a positive than a negative effect.

During evaluations, we will collect the following types of data. We will collect quantitative data from recording student interactions and observing student and instructor behaviors. We will also collect qualitative data from focus groups, student survey, interviews, and voluntary student feedback.

Quantitative data:

- Attendance and/or classroom participation
- Effects on note-taking behavior.
- Effects on seating behavior.
- Increased or continued use (even without study requirements) would likely imply that students see the technology as valuable.

Qualitative data:

- Students' self-reflections on access to classroom content, note-taking behavior, participation, performance, learning experience and feeling of inclusion.
- Effects of classroom engagement.
- Students' perception of the technology as a useful in-class tool.
- Students' perception of the technology as a useful study tool.

We are currently collaborating with Rochester Institute of Technology (RIT), home of the National Technical Institute for the Deaf (NTID) supporting over 400 deaf students in the academic mainstream, over 120 sign language interpreters, and over 50 captioners. Evaluation of the technology will take place in mainstream classrooms at the University of Washington using both technical and human resources at RIT.

Another excellent opportunity for evaluation and feedback is the Summer Academy for Deaf and Hard of Hearing Students hosted each summer at the University of Washington. The top ten deaf college freshmen or sophomore applicants join the program to take college courses focused on introductory Java programming, computer science, and related fields. Because the academy involves mainstream courses, it presents an ideal testbed situation. Students who are interested in participating will be asked to use the technology, including a remote sign language interpreter or captioner, during class time and rate its usefulness through a series of questionnaires. Weekly one-on-one interviews will be conducted to discuss problems, suggestions, and other feedback.

5.5. *Timeline*

Spring 2008

- Prepare a working prototype of the classroom technology for the DHH Cyber Community Summit gathering in June 2008.

Summer 2008

- Implement and evaluate an initial version of the classroom technology locally at the University of Washington.
    i. This version will be fully functional, but may not include all of the desired features, such as capture.
- Conduct evaluations with students from the Summer Academy for Deaf and Hard of Hearing.

Fall 2008

- Use feedback from the summer release to improve the design of the system.
- Create an online repository for capture and retrieval.
- Implement and evaluate the classroom technology with interpreters and captioners at RIT and students at UW.
- Execute a formal user study to determine the best digital educational environment using the classroom technology.

Winter 2009

- Iterate improvements to the system based on the results from the formal user study.

Spring 2009

- Continue to improve and develop.
- Begin longitudinal studies with UW students to investigate long term use and results of any novelty factors.

Summer 2009

- Release and evaluate at Summer Academy for Deaf and Hard of Hearing and compare results to previous summer academy.

Fall 2010

- Finish remaining analysis and research.
- Prepare dissertation and defend.

6. Conclusion

Our primary research goal is to find ways to increase involvement of deaf and hard of hearing students in university academics. With this goal in mind, we will strive to broaden the accommodation resources for students through high-bandwidth remote interpreting, reduce the visual dispersion of important in-class components through on-screen consolidation, and encourage in-class inclusion through new channels of communication and interaction. Solutions will be viable for traditional classroom environments as well as for lab sessions, study groups, and project meetings. And because our work will parallel that of other educational technology, we will follow universal design guidelines so that the technology used by deaf and hard of hearing students is compatible and seamlessly coexists with educational technology designed for a general, mainstream audience. By utilizing networked resources and flexible design that empowers students, we hope to create a more inclusive, easily accessible classroom environment.

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Inclusion of Deaf Students in Computer Science Classes using Real-time Speech Transcription

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ABSTRACT

Computers increasingly are prevalent in the classroom, with student laptops becoming the norm, yet some beneficial uses of this widespread technology are being overlooked. Speech recognition software is maturing, and possesses the potential to provide real-time note taking assistance in the classroom, particularly for deaf and hard of hearing students. This paper reports on a practical, portable and readily deployed application that provides a cost-effective, automatic transcription system with the goal of making computer science lectures inclusive of deaf and hard of hearing students. The design of the system is described, some specific technology choices and implementation approaches are discussed, and results of two phases of an in-class evaluation of the system are analyzed. Ideas for student research projects that could extend and enhance the system also are proposed.

Categories and Subject Descriptors

K.4.2 **[Computers and Society]**: Social Issues – *Assistive technologies for persons with disabilities.* H.5.2 **[Information Interfaces and Presentation]**: User Interfaces – *Voice I/O.*

General Terms

Design, Experimentation, Human Factors.

Keywords

Speech recognition, computer science education, inclusion, accessibility, deaf students, hard of hearing students, assistive technology.

1. INTRODUCTION

Advances in affordable portable computing technology have led to wider availability, making it possible to deploy automatic speech recognition (ASR) in the classroom, although challenges remain [3]. The ability of ASR systems to transcribe continuous speech faster than a note taker can write, with reasonable accuracy and minimal training, make them a viable option to assist deaf and hard of hearing students with note taking [5]. Computer science continues to be a popular choice of college major for high school students with hearing disabilities [1], although these students can find traditional accommodations such as sign language interpreters or lip-reading insufficient [10]. Technology such as speech recognition can provide a viable solution, but awareness of accessibility issues continues to be the most significant hurdle to inclusion [4].

Obstacles to relying on ASR for note taking include recognizing multiple or random speakers [5], synchronizing and incorporating visual cues [9], balancing real-time automated speech text against the potential for distraction [6], insufficient accuracy in recognizing domain-specific jargon [5], configuring, training and deploying the ASR system for classroom use [2], and achieving acceptable accuracy through microphone selection, improved software and additional training of the ASR system [11].

Active research in ASR for college classrooms is being done by the Liberated Learning Project (LLP), among others [5,6,2,11]. The LLP has the goal of enabling students with various disabilities, including hearing impairment, to maximize the benefits of the college lecture experience [8]. Significantly, the LLP has collaborated with IBM to develop the ViaScribe software that is specifically designed for real-time captioning, including ASR, of natural, extemporaneous speech. ViaScribe improves readability by detecting pauses in speech and inserting sentence and paragraph breaks, provides phonetic spellings when the recognizer is uncertain, and even has a less-accurate speaker-independent mode to accommodate multiple speakers [3].

Accuracy of reasonably well-trained ASR systems typically is better than 75-85% in classroom lecture settings, with rates over 90% for particularly consistent and clear lecturers [5,11], a rate that a significant majority of students find acceptable and useful [6]. A centralized ASR system producing real-time captioning on a projection screen with post-lecture access to a transcription has been used successfully in the classroom [11], although a more individualized approach often may be preferable [3,6,11].

This paper presents the design and evaluation of the Villanova University Speech Transcriber (VUST) system that increases accessibility of computer science lectures for deaf and hard of hearing students using real-time speech recognition software. This study was conducted at the Applied Computing Technology Laboratory at Villanova University (actlab.csc.villanova.edu), and

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evaluates the impact of the VUST system paired with our Dictionary Building Software utility (DiBS) [7] on the effectiveness of a portable, centralized, affordable, laptop-based ASR system designed to augment note taking by deaf and hard of hearing students in the college classroom. Although the original motivation for development of the system was to improve accessibility of computer science lectures specifically, the system holds potential for much wider applicability.

2. SYSTEM DESIGN

The VUST system consists of three major components: the speech recognition software, a dictionary enhancement tool, and a transcription distribution application. Figure 1 illustrates the VUST architecture, showing these major components and other elements of the system.

The dotted line in Figure 1 indicates the physical computer on which the speech recognition engine, VUST server application, wireless microphone receiver and other elements are located. One or more client applications can connect to the server, and a wireless headset microphone transmits speech to the server for processing.

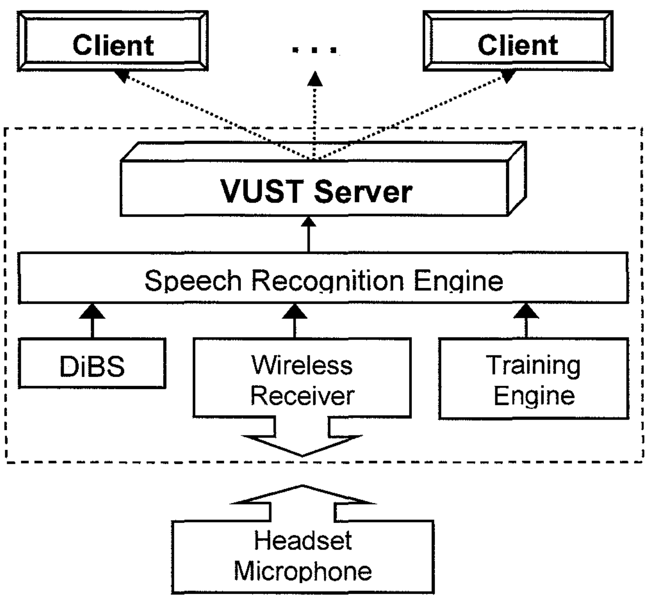

Figure 1. VUST System Design.

2.1 Speech Recognition System

The speech recognition system uses an ASR system designed to be affordable, accurate and easy to set up and use. The Microsoft Speech Recognition Engine (MSRE) was selected due to the wide availability in academic institutions of the Microsoft XP platform, which includes the MSRE, effectively providing the ASR engine for our system at no additional cost.

The Nady Systems UHF-3 wireless unidirectional headset microphone was selected as a cost-effective solution ($120-$140), with unrestricted movement, high directionality and good tolerance of interference being key considerations when selecting a microphone for ASR [7].

The MSRE is trained by an instructor via a control panel included with the engine. The instructor reads from a selection of available text scripts into a microphone, enabling the recognition engine to learn to recognize the specific words as spoken by the specific instructor. The maximum level of training that was tested in our evaluation required less than one hour, with 30 minutes of script-based training, 5 minutes to run the dictionary tool, and 10 minutes of additional training to record pronunciations of domain-specific words.

Setting up and running the system involves ensuring the instructor's computer is appropriately networked, connecting the wireless microphone receiver and putting on the wireless headset, activating the MSRE via the Windows Speech control panel, and starting the server application. Once the system is running, students can connect via a simple web page containing the client application. The instructor controls the location and content of this web page.

2.2 Dictionary Tool

The Dictionary Building Software tool (Figure 2) analyzes textual input, scanning for domain-specific terminology to add to the speech recognition system custom dictionary (i.e., "custom.dic"). DiBS parses an input file into words, filtering words below a minimum length threshold, that appear in a standard system dictionary, and that already appear in the custom dictionary. The minimum length threshold of six characters limits the words considered to those with a higher likelihood of being domain-specific, which tend to be longer in length.

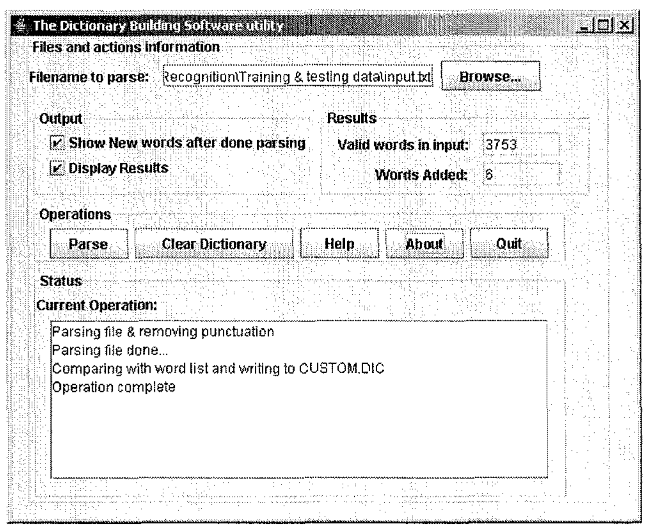

Figure 2. Dictionary Building Software (DiBS) utility.

The key innovation of the DiBS tool is the ability for the user easily to add domain-specific terminology to the MSRE custom dictionary in one, simple step. Prior to DiBS, the method for customizing the dictionary and improving recognizer accuracy was well hidden in obscure documentation, and involved a number of non-intuitive steps. The DiBS tool streamlines the process so that minimal time and no technical expertise is required in order to customize the dictionary, thereby improving the accuracy of the recognition engine, and therefore likelihood that the speech recognition system will be used.

The speech recognition engine relies on a static system dictionary for its basic recognition, with syntax rules built into the recognizer that phonetically match utterances with corresponding words. Secondly, the recognizer uses words in the custom dictionary in a similar way. DiBS improves recognition accuracy by adding terminology to this custom dictionary.

If a user notes that some terminology is still not being recognized, which can happen if the word uses exceptions to typical rules of pronunciation or is particularly complicated, word-specific training can be performed by the user. This training is part of the underlying Windows XP speech recognition system, and is done using a training interface linked to the custom dictionary.

2.3 Transcription Distributor

The VUST consists of a text distribution server application and corresponding client application, both implemented in Java. The server and client are based on common chat server architecture, modified to accept input from the speech recognition engine and with client chat-back disabled. The design of VUST was kept minimal and straightforward to support a design goal of ease of use. Capture and acquisition of a lecture transcription had to be easy so that any instructor could deploy and use the system, and any student would find it easy to read and save the result. Java was selected as the implementation language to ensure portability across platforms, including Macs, PCs and Linux machines.

The VUST server receives the textual output of the recognition engine, and immediately forwards it to any client applications that are connected. The client application is a Java applet (Figure 3), embedded on a simple web page provided by the instructor, and automatically connects to the VUST server when the page is accessed. If the client fails to connect to the server, a message appears on the client indicating this failure.

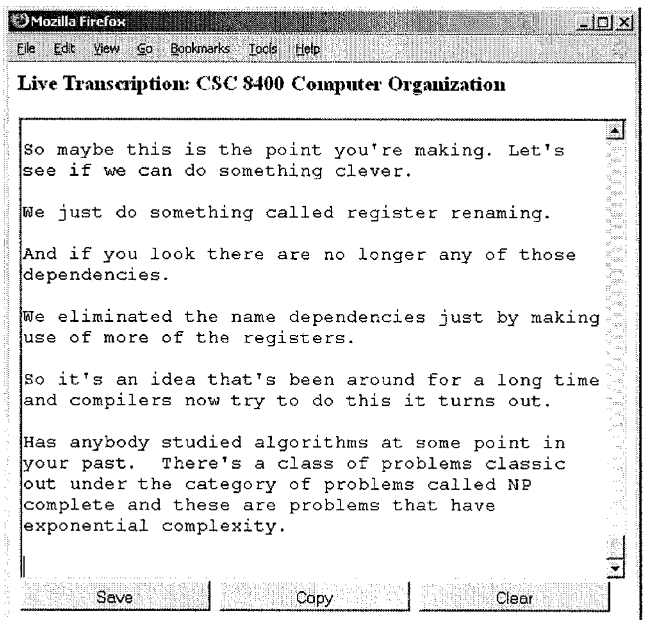

Figure 3. VUST Transcription Client applet.

In the sample of captured text in Figure 3, when brief pauses are detected, a period is inserted in the text, while longer pauses lead to the insertion of a paragraph break. In the last block of recognized text, even though the last sentence obviously contains some errors, it still maintains the intended meaning of the spoken sentence. This is typical of an acceptable form of recognition error.

In addition to presenting the live transcription of the lecture, the client also allows the student to export the transcription to a text file, copy and past it to another program, or clear the current transcription from the screen. A pop-up dialog prevents the student from accidentally clearing a transcription in progress without first confirming the desire to do so.

3. Evaluation

The VUST system was evaluated as a standalone, centralized speech transcription system for recognition accuracy, perceived accessibility and deployability. The system was tested in a controlled environment in an empty classroom using prepared lecture notes, and in a real classroom setting. An initial study was performed to measure the effectiveness of the DiBS tool on improving recognition accuracy. A follow-up study making use of the full VUST system was conducted to determine how the system would perform in an authentic lecture setting.

3.1 Improving Accuracy

The initial study measured the effectiveness of the DiBS utility to improve the recognition accuracy of the Microsoft Speech Recognition Engine (MSRE). The engine was prepared and tested using five training scenarios: untrained, minimally trained, moderately trained, moderately trained with a customized dictionary, and moderately trained with a customized dictionary and selected customized pronunciations.

The DiBS utility analyzed a number of text files containing the content of technical papers and lecture notes related to the subject matter of selected computer science lectures. Custom pronunciations were recorded using the MSRE training interface for approximately 10 domain-specific words that the MSRE had difficulty recognizing.

Tests were performed using spoken lectures containing terminology-rich material from undergraduate and graduate courses in computer architecture, totaling approximately 3,700 words or 30 minutes of continuous speech. The lectures were conducted in a classroom by a computer science professor wearing a wireless headset microphone, using a very clear and consistent speaking style, and were digitally captured to WAV files. To enable valid comparison, these digitized lectures were then replayed to the MSRE running on a university-issued laptop, under five training scenarios, with the transcription output captured into a Microsoft Word file. Objective measures of accuracy were made using a free text file comparison tool called DiffDoc (softinterface.com) by comparing the output of the speech recognizer with a human transcription of the original lecture. Results of the file comparison tool were analyzed manually for verification.

Table 1 shows the results of evaluation of the recognition engine for accuracy and accessibility under the five training scenarios. Accuracy improved with additional training, with marked improvements when going from an untrained to a minimally trained system (from 75% to 88% accurate) and with the addition of a customized dictionary and pronunciations to a moderately trained system (from 91% to 94%). The recognition accuracy varied greatly (plus or minus 5-10%) depending on the prevalence of terminology that was not found in the default ASR dictionary. Adding terminology from the domain of the lecture helped, and additional recording of pronunciations of specific terminology that the recognizer still misrecognized helped more.

Table 1. Comparison of recognition accuracy, range of accuracy, and accessibility.

Description	Accuracy	Range	Accessibility
Untrained	75%	64-83%	poor to fair
Minimal training (default script, 10 minutes total)	88%	78-93%	sufficient
Moderate training (3 additional scripts, 30 minutes total)	90%	81-96%	good
Moderate training, customized dictionary	91%	83-96%	good
Moderate training, customized dictionary, customized pronunciations	94%	86-98%	very good

Accessibility of the resulting transcription was measured by reading the transcript and in effect grading it as if it were a student report summarizing the content of the lecture. This more subjective accessibility of each transcript was judged broadly to be: poor, fair, sufficient, good, very good, excellent. Even with minimal training, the results were passable (sufficient), although they required careful reading and some editing to make them usable as notes. With moderate training, transcripts were usable (good) as class notes with only minor editing, such as inserting paragraph breaks.

Although very good accessibility was achieved with the addition of some customized pronunciations, excellent accessibility was not achieved in any of the scenarios, reinforcing the need for continued research in speech recognition technology [1]. It is important to note that, although recognition at times reached well above 90% accuracy, a very good result, these results may be artificially optimistic due to the constrained nature of the quiet test environment, consistent speech and chosen material. The second phase of evaluation was designed to measure recognition in a more realistic classroom setting.

3.2 Measuring Deployability

To determine whether speech recognition could be a beneficial classroom technology for increasing accessibility of computer science lectures for deaf and hard of hearing students, the VUST system was deployed in a real lecture setting. For this experiment, the full system was used by the instructor in a regular computer architecture class meeting which included a hard of hearing student.

An entire 90 minute lecture consisting of nearly 10,000 words was transcribed using the VUST system, and the transcription output was saved to a text file and also transcribed manually for comparison. The instructor then analyzed the transcript and identified all misrecognitions, within reasonable constraints (e.g., singular vs. plural and homonym misses were allowed when the meaning was intact, while obviously incorrect recognition or anything that hurt the meaning was marked as incorrect). The automatic and manual transcriptions were then compared for accuracy. Sections of the transcript were classified based on their speech content, as: roll-call (list of names or otherwise discontinuous speech), planning (assignments, dates, general classroom business), discussion (interaction including student discussion), and lecture (continuous instructor speech).

Not surprisingly, the best recognition accuracy was achieved with prepared lecture, resulting from the MSRE preference for continuous speech. Note that the DiBS utility was not used in this phase of experiments to enable clear distinction among classifications of speech and effectiveness of the client-server approach. Overall accuracy was 85%. Planning, lecture and discussion were all consistent with this average, with roll-call scoring the lowest (61%). Table 2 summarizes the results obtained using the VUST.

Table 2. Comparison of VUST recognition accuracy with four classifications of speech content.

Classification	Words Correct	Total Words	Percent Recognized
Planning	628	758	83%
Lecture	5930	6925	86%
Roll-call	155	254	61%
Discussion	1556	1846	84%
TOTAL	**8269**	**9783**	**85%**

The low recognition accuracy (61%) of roll-call speech was not unexpected. A student name can be a form of domain-specific terminology all to itself, and are not likely to be found in the static system dictionary. Planning speech scored next lowest (83%), due to its disjoint, bullet-item nature, also lacking the continuous flow that the MSRE prefers. Discussion and lecture speech were both recognized at relatively acceptable rates, deemed very usable by the instructor and student who participated.

Student reaction to the VUST system was striking. The experience of real-time transcription was described as a "totally new experience" and of enormous benefit. The hearing-impaired student found himself raising his hand to contribute to a classroom discussion for the first time, having followed along with the help of the VUST transcript. Other (hearing) students who had access to the transcript following the class found it to be a useful supplement to their notes, and they remarked at how closely the transcript matched what occurred in class.

4. CONCLUSIONS AND FUTURE WORK

The VUST system shows significant promise as an affordable and beneficial assistive system to make the computer science classroom more inclusive for deaf and hard of hearing students. Although the benefits of a sign language interpreter or prepared lecture note handouts is recognized, both require additional and regular cost or preparation. By enabling the use of a automated, real-time transcription, cost and preparation overhead is reduced and accessibility is increased.

Providing easy to use software that can improve recognition accuracy and make distribution of a real-time lecture transcription contribute to making VUST very usable by instructors and students. Customizing the dictionary of speech recognition system with domain-specific terminology is effective at improving accuracy. The DiBS tool provides an efficient means to automatically cull such uncommon jargon from large amounts of text and customize the recognition engine, in this case the MSRE. Although DiBS only considers new terms that are six characters or greater in length as an optimization, shorter domain-specific terms can be added manually by an instructor.

An alternative use of VUST could be in stand-alone mode, running on a student laptop. In this configuration, a student would provide a wireless microphone to the instructor and capture the lecture transcription directly on the student computer. However, effective use of ASR in this way requires the student laptop to contain a speech profile trained by the instructor. Using the Speech Recognition Profile Manager Tool (microsoft.com), a speech profile can be imported or exported, making possible distribution of the profile, along with custom dictionaries for specific topics, via a central repository such as a university or department web site. In this way, a student can install such a speech profile of a particular instructor and immediately improve recognition accuracy.

It is important to note that although VUST generates a transcription that can improve accessibility, it is not a replacement for attendance and the very real benefits of being physically present and interactive in a lecture setting. Recognition technology has advanced considerably in recent years, yet accuracy is still far from producing lecture notes on par with what an instructor would prepare by hand. The VUST transcript is best used to assist and augment note taking, much as a student uses a spoken lecture to add detail and clarification to material gleaned from slides or board work.

Because VUST and DiBS are implemented using Java, and the system consists of distinct software components, there are many opportunities for student research and development projects. One project could involve improving the DiBS tool to harvest more domain-specific terminology from a variety of sources. DiBS currently only accepts text input, but available Java add-ons could make it possible to parse PDF and MS Word documents, further improving the usability of the system.

Another potential project is the development of a corpus of domain-specific terminology, ready-made for computer science that could be used as customization input to the DiBS tool. This collection could be extended to other terminology rich subjects, such as biology, engineering, philosophy, and others, further increasing accessibility to real-time lecture transcription.

Future work includes plans to produce a commercial-quality version of the VUST and DiBS software, design of a centralized repository system for domain specific terminologies and speech profiles, and evaluation of other cost-effective speech engines.

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NTID RESEARCH BULLETIN

Center for Research, Teaching and Learning · National Technical Institute for the Deaf · Rochester Institute of Technology

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Lisa Elliot is a research associate in the Department of Research at NTID.

Michael Stinson is a professor in the Department of Research at NTID.

C-Print Update: Recent Research and New Technology

by Lisa B. Elliot and Michael S. Stinson

C-Print™ refers to a family of computer-assisted, speech-to-print technologies. Here, we briefly describe the service and review recent findings and forthcoming enhancements to the system. Since 1990, approximately 1000 deaf and hard-of-hearing students have been supported in educational environments through use of C-Print and over 500 individuals from approximately 350 educational programs in at least 46 states and 4 foreign countries have completed the month-long training to become a C-Print captionist. C-Print has been widely disseminated beyond NTID and is now frequently requested by deaf and hard-of-hearing students around the world. For a background in the C-Print system, see articles in the *NTID Research Bulletin*, *1*(3), Fall 1996, and *5*(2), Spring 2000.

Background

C-Print includes both automatic speech recognition (ASR) and computerized word-abbreviation approaches to transcribe speech into text. New software developed by the project provides communication between computers and provides displays for the captionists and students. C-Print does not produce verbatim text but uses summary techniques to capture as much of the meaning as possible. It was developed after many years of research at NTID with another speech-to-text system, called Communication Access Real-time Translation (CART), that uses stenographic equipment to produce verbatim text. Students were happy with the CART text, but researchers realized that for many school districts, the expenses associated with the system were much too great.

Research with College Students: 1993-1996

The first large-scale study using C-Print ran from 1993-1996 on the campus of RIT (Elliot, Stinson, McKee, Everhart, & Francis, 2001). Over this three-year period, 36 deaf and hard-of-hearing students who were mainstreamed into 32 business and liberal arts classes, and who also were supported by interpreting and notetaking, used the C-Print support service. These students participated in questionnaire and interview studies in which they provided feedback about the support service. Twenty-two of the 36 students were also interviewed.

Questionnaire items included student ratings of lecture comprehension. These ratings indicated good comprehension with C-Print, and the mean rating was significantly higher than that for understanding of the interpreter. Students also rated the hard copy printout provided by C-Print as helpful, and they reported that they used these notes more frequently than the handwritten notes from a paid student notetaker. Interview results were consistent with those for the questionnaire.

Questionnaire and interview responses regarding use of C-Print as the only support service indicated that this arrangement would be acceptable to many students, but not to others. Data from school records were also correlated with students' questionnaire responses, and communication characteristics were related to responses to the questionnaire. Students who were relatively

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Notes of Note

On January 24, 2003, **Susan Fischer** presented a colloquium related to her cross-linguistic sign language research to the linguistics department of the University of Toronto. For more information she can be contacted at *SDFNCR@RIT.EDU.*

Oxford University Press has just published the *Oxford Handbook of Deaf Studies, Language, and Education*, edited by **Marc Marschark** and **Patricia Spencer** (Gallaudet University). In describing the volume, RIT Vice President for NTID, Robert Davila said, "In my opinion, over the course of the past 40 years, no other deaf studies publication offers a more comprehensive and authoritative perspective of the social, psychological, linguistic, and pragmatic aspects of deafness." The 672-page handbook contains 36 chapters, including chapters by **John Albertini** and **Sara Schley**, **Harry Lang**, **Michael**

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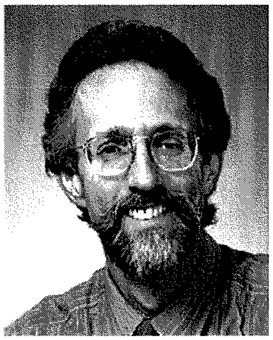

Accommodation and Access

"Will I have an interpreter for this class?"
"Will the boss be accommodating?"

Such questions run through the minds of deaf and hard-of-hearing students and employees daily. Sign language interpreters, note takers, and newer support services, such as C-Print captionists, are accommodations that provide students and employees access to lecture, presentation, and discussion. At school and in the workplace, it is often up to the deaf or hard-of-hearing person to request accommodation or changes that will improve access to information and communication. According to the *Oxford English Dictionary (Third Edition)*, to accommodate means to reconcile persons who differ and to bring persons who differ to harmony or agreement. Where differences become barriers, reconciliation will open the way to communication and information.

Though serious disagreements continue over what constitutes "reasonable accommodation" and how to achieve it, we are certain of two things. We know that new speech-to-print technologies can improve students' access to classroom discourse and that legislation (for example, the Americans with Disabilities Act, 1990) can only promise due process. Accommodating peoples' differences and providing equivalent access to all learners and employees are complex processes, and we are fortunate to have two research reports in this issue of the *NTID Research Bulletin* that shed light on them.

The first report by Lisa Elliot and Michael Stinson (NTID Department of Research) brings us up-to-date on the use of new speech-to-print technologies in mainstream high school and college classrooms. The C-Print program of research has spawned software and hardware development, training, and prototype evaluation. The goal of the program has always been to develop sound new technologies that will improve access and enhance learning in the classroom. For balance and focus on the workplace, we invited our colleague David Baldridge (College of Business, RIT) to summarize what he found to be the key personal and contextual variables leading an employee to request or not to request changes in the workplace. Twelve years after the Americans with Disabilities Act was signed into law, employees still hesitate to request accommodation.

Future issues of the Bulletin will report on other studies of access and accommodation, a main focus of activity in the Department of Research at NTID. As always we hope you find these reports thought-provoking and helpful and that you will send us your comments and suggestions via the NTID Research Advisory Group's website at *http://www.rit.edu/490www/RAG*. Also, please check out the Department of Research's new website at *http://www.rit.edu/ntidresearch*.

John A Albertini

John Albertini
Chair, Department of Research

NTID Research Bulletin
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C-Print Update continued from page 1

proficient in reading and writing English, and in speechreading, responded more favorably to C-Print.

Research with High School and College Students: 1996-1999

With support from the U.S. Dept of Education, we were able to expand our research to three college and university settings in the Rochester, NY, area, and to public high schools in greater metropolitan Rochester, and in Irvine and San Diego, CA. Two additional interview (and questionnaire) studies and a controlled experiment have been conducted.

Interview studies. Interviews were conducted with 75 participants (25 high school students, 14 college students, 14 high school classroom teachers, 10 high school teachers of the deaf, and 12 college professors) about their experiences with the C-Print system.

One study focused on students' and teachers' use of C-Print notes (Elliot, Foster, & Stinson, 2002). Consistent with research on normally hearing students, high school students in this study typically would read the notes only, while college students used multiple study strategies with the notes. Teachers tended not to know how their students used their notes for studying and they were sometimes reluctant to teach students about effective note usage. This study supports the idea that both students and teachers could benefit from further instruction on note usage and study skills.

In another study, we analyzed teachers' acceptance of C-Print as a support service in their classrooms. Previous research has found that student success using an assistive technology may be, in part, attributed to educators' acceptance of the technology. Using Rogers (1995) model of "diffusion of innovations," we found that educators accepted C-Print due to its relative advantage over other notetaking services, that is, the perceived simplicity of the system and its perceived potential for students. However, some educators, who prefer eye contact with their students as an indication that students are participating in class, were resistant to C-Print because the technology requires students to focus their attention on a computer. We also learned that educators who were more accepting of the service had different perceptions of their initial introduction to the service; they recalled being asked to participate in trials of C-Print in their classrooms, whereas less accepting teachers perceived that they were "told" a student would be trying C-Print. Successful implementation of assistive technology can satisfy both the needs of the student and the values of the educator when everyone's needs and values are taken into account.

Successful implementation of assistive technology can satisfy both the needs of the student and the values of the educator when everyone's needs and values are taken into account.

Experiments. Data are currently being analyzed for two controlled experiments. In one experiment, participants were 48 deaf and hard-of-hearing high school students, mostly from San Diego. Students were randomly assigned to one of three experimental conditions. In Condition 1, students viewed a brief (15 minute) videotaped lecture about Japanese-American history. At the same time, on a different television screen, they watched either C-Print captioning of the lecture or a videotape of an interpreter. After the videos concluded, students took two brief quizzes—a recall test (fill-in-the blank) and a recognition test (multiple choice).

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continued from page 1

Stinson, and Marc Marschark. For additional information about this publication, contact Marschark at *MEMRTL@RIT.EDU.*

In November, Marc Marschark was invited by the Taiwan Association for the Deaf and the Taiwan National Teachers College to present a series of lectures in Taiwan. The lectures served as keynote addresses for conferences in Taipei and Tainan on deaf education and will be published (in Mandarin) by the Taiwan Association for the Deaf.

Bob Whitehead and colleagues recently published an article, "Preservation of place and manner cues during simultaneous communication: A spectral moments perspective" (Kardach, J., Wincowski, R., Metz, D.E., Schiavetti, N., Whitehead, R., & Hillenbrand, J. (2002). *Journal of Communication Disorders, 30,* 533-542). Spectral moments, which describe the distribution of frequencies in a spectrum, were used to investigate the preservation of acoustic

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Michael Stinson is leader of the team that has developed the C-Print speech-to-text system. He currently directs projects funded by the US Department of Education to incorporate automatic speech recognition into the C-Print system and to provide training in C-Print nationally. He is also a member of the faculty of the graduate program that prepares teachers of the deaf and has taught in the program in school psychology at RIT. Stinson has presented and published extensively on instruction of and social integration of deaf and hard-of-hearing students in general education classrooms, as well as on effects of technology, interpreting, notetaking, and tutoring. Stinson is deaf and he received all his education in mainstream classes. For more information, he can be reached at MSSERD@RIT.EDU.

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...students do at least as well, and in some instances better, in retaining information with a C-Print presentation than with an interpreted one.

Students also completed demographic data including communication preference. The following week, students returned and watched another lecture, this time accompanied by either C-Print or an interpreter (whichever format they did not receive in session one).

In Condition 2, students followed a similar protocol to Condition 1, except that before they received the quiz, students were given a copy of notes about the lecture to study. If students viewed the C-Print captioning, they then received the notes generated by C-Print. If the students viewed the video with the interpreter, they then received handwritten notes produced by a notetaker. After reviewing the notes for up to 20 minutes, students took the two quizzes.

In Condition 3, students attended the experiment for four separate sessions. In sessions one and three, students viewed the videos and received notes to study. In sessions two and four, students again reviewed the notes and then took the quizzes.

A key finding for the experiment with the high school students was that students retained significantly more information from the C-Print presentation than from the interpreted one. This result is consistent with that of the questionnaire study, because it indicated that students do at least as well, and in some instances better, in retaining information with a C-Print presentation than with an interpreted one. For both the C-Print and interpreted presentations, students remembered more information in Condition 3, in which there was a delayed test and additional time to study the notes, than in Condition 1 (no notes) or Condition 2 (notes and immediate test), suggesting that the combination of notes, the opportunity of additional time to review them, and the delay in testing facilitated performance.

The second experiment involved the participation of 48 deaf and hard-of-hearing college students at RIT. This experiment followed the same format as the high school experiment, but used different videotapes. The college videos were excerpts from actual sociology lectures given by a professor at RIT. Results for this experiment were more complicated than those for the first experiment. For Condition 1, in which students were required to remember specific terms without the benefit of reviewing notes or printed material, students recalled more information with C-Print than with an interpreter. In particular, for the C-Print presentation, students did not do significantly better in Conditions 2 and 3 when they had C-Print text for study after viewing the real-time display than when they did not. However, for the interpreted presentation, students did better when they had notes from a notetaker than when they did not.

One interpretation of these results is that, for the C-Print presentation, students retained enough information regarding specific terms, spelling, etc., that they did not need the text to resolve ambiguities. However, for the interpreted presentations there were such ambiguities, and consequently, the opportunity to review these notes helped to clarify uncertainties about specific terms in the lecture. These results need to be interpreted in the context of the finding that there were not overall differences in retention (both recall and recognition tests) for the interpreted and C-Print presentations (Stinson et al., 2000).

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cues, e.g., place and manner of articulation, to intelligibility of speech produced during simultaneous communication (SC) in relation to those acoustic cues produced when speaking alone. The spectral moments obtained from speech produced during SC were indistinguishable from those obtained during speech alone, indicating no measurable degradation of obstruent spectral acoustic cues during SC. For more information on this research, contact Whitehead at *RWWNCR@RIT.EDU.*

For the past two years, **Harry Lang** has been developing a website for the dissemination of information to promote learning by deaf and hard-of-hearing students. COMETS (the Clearinghouse On Mathematics, Engineering, Technology and Science) is a project funded by the National Science Foundation to enhance science, technology, engineering and mathematics education for deaf and hearing students. This website provides

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LaTonja Adams, C-Print captionist, and Kevin Barker.

Implications from the Research

Implications from the research conducted with C-Print to date has allowed us to fine tune and improve the system in many ways. For example, based on feedback from students and teachers, we are developing new training materials that will help students and their teachers get the most out of the C-Print experience. This will include workshops for teachers and parents, and printed and on-line instruction for effective software usage and study habits. Feedback we received from captionists has also resulted in physical changes to the C-Print software system and its implementation, which we will cover in the following section.

Looking Ahead to the Future of C-Print

C-Print user-interface software. In the past, captionists used three commercially available software programs running simultaneously—a word processing program, a typing abbreviation program, and a communications program that allows captionist and student computers to "talk" to one another. Based on feedback from captionists, we created an in-house software, called C-Print Pro©. C-Print Pro does everything that the three programs used to handle, only better! For example, in addition to allowing captionists to shorten their typing time with fewer keystrokes, students can also highlight their notes, make their own notes on the screen during class, and even type questions to the captionist without interfering with captioning.

Integrating ASR with C-Print allows captionists to continue captioning long after one hour.... Preliminary research suggests that using ASR, captionists capture about 83% of all idea units and are producing text that is 97% accurate.

In developing these features of the software, the C-Print team kept in mind the difficulty of deaf students simultaneously focusing on watching the teacher or real-time display and taking good notes. Project staff designed the highlighting and notetaking features so that students can use them with minimal diversion from attending to the teacher and/or the real-time text display.

Automatic speech recognition. One limitation of a typing-based system at the postsecondary level where classes are often longer than an hour is fatigue. Prolonged typing may lead to pain and injury. With ASR, captionists can utilize their voices instead of their hands. Integrating ASR with C-Print allows captionists to continue captioning long after one hour. Instead of typing, the captionist speaks into a microphone that is covered with a sound baffler—a dictation mask—that is connected to the computer (Stuckless, 2000). We chose to use an intermediary approach, which requires the presence of a captionist, because ASR technology is not yet sophisticated enough to capture nuances of speech, add punctuation, or detect multiple voices. Our intermediary captionist is able to insert this information into the text and make it readable for the student. Preliminary research suggests that using ASR, captionists capture about 83% of all idea units and are producing text that is 97% accurate (Elliot, Harradine, & Stinson, 2002).

Next steps for the project will be to implement ASR and the new software in high school and college classrooms, adjusting the system to make it even more effective. With both ASR and word-abbreviation approaches to producing text and the new C-Print Pro software, the system is more flexible. In addition, drawing on research and experience, the project will develop new materials that should better help students make the most out of their experience with C-Print.

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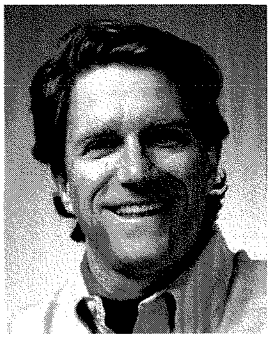

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Workplace Accommodation: Is it Really Okay to Ask?

by David C. Baldridge

Introduction

This study investigated situational attributes that influence employees' decisions to request, or not request, needed workplace accommodation due to perceived normative appropriateness—that is, *do others think I should ask?* Past studies (e.g., Florey, 1998; McLaughlin and Gray, 1998) have shown significant reluctance to request needed accommodations. Currently little is known about factors that influence the favorability of requesters' assessments and the likelihood of withholding a request based on perceived normative appropriateness, i.e., what situational characteristics will keep an employee from requesting needed workplace accommodation because s/he believes *others* think accommodation should not be requested?

...the social environment not only influences personal assessments regarding the cost of asking for help, but also influences normative assessments about when help should or should not be sought.

Based on a review of the help-seeking and workplace-accommodation literatures, four requester attributes—age, sex, age of disability onset, and disability severity—and three workplace attributes—employer size, supervisor relationship quality and co-worker relationship quality—are hypothesized to influence the extent to which requests are withheld due to normative assessments. Survey data from 250 deaf or hard-of-hearing, full-time employees was used to test these hypotheses. Details of the study and full results are available from the author.

Theory

Given the paucity of research on the perceived normative appropriateness of requesting accommodation, literature from "help seeking" was used in conjunction with the literature on "workplace accommodation."

Normative appropriateness. In the accommodation literature, a distinction is drawn between individuals' personal assessment regarding an action or behavior and their normative assessments of what others think they should do. Both are predictors of intentions and accommodation-requesting behavior (Baldridge and Veiga, 2001). Gross and McMullen (1983) showed that the social environment not only influences personal assessments regarding *the cost* of asking for help, but also influences normative assessments about *when* help should or should not be sought.

Request attributes. Lee (1997) identified two individual attributes thought to influence the level of help seeking: sex and status differential. Women generally perceive greater normative support. In many cultures men are expected to be more self-reliant and independent. Individuals were less apt to make requests when they feared losing power, and Baldridge and Viega (2001) suggest greater risk of losing power when a request is more likely to reveal new, and perhaps unfavorable, information and when it will change others' perceptions of the requester. Men, younger workers with less severe losses and those who lost their hearing later in life are more likely to withhold requests for needed accommodation.

Request context. Requesters try to seek help from others who will be less burdened by providing assistance (Anderson and Williams, 1996). Baldridge and Viega (2001) suggest that overall relationship quality may influence a requester's assessments on normative appropriateness of requesting

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many resources, including informational pages and complete "workshops" on a variety of topics, which can be used individually by teachers, in pre-service teacher education courses as lessons, or as actual workshops for in-service professional development programs to help teachers interested in renewing certification. The COMETS website is at *http://www.rit.edu/~COMETS*. For more information, contact Lang at *HGL9008@RIT.EDU*.

Susan Foster (PI) and **Gary Long** (Co-PI) have recently receided funding from two programs at the US Department of Education for three year projects to promote access and inclusion for deaf and hard-of-hearing students in postsecondary education. The two awards, totaling over $1M, will allow the project team, including Rosemary Saur (Department of Science and Engineering Support at NTID) and faculty, staff and students from

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accommodation. Thus, requesters in smaller organizations, with few resources, and with lower quality relationships with supervisors and co-workers are more likely to withhold requests for needed accommodation.

...the perceived normative appropriateness of requesting accommodation was more a function of general relationship quality than organization's resources.

Methods

The current study focuses on one disability group—people who are deaf or hard of hearing. Surveys regarding workplace accommodation were sent to 688 individuals; 250 usable surveys were returned (36.3 percent). No significant difference was found when comparing the age, sex, and educational level of those who completed the survey and those who did not. For the final sample, 53 percent of the respondents were women; the mean age was 40 with a range of 21 to 63 years. Existing measures were available for the same or similar constructs. Therefore, rather than develop entirely new measures, existing measures were modified and verified.

Discussion

As expected, both attributes of the *requester* and the *request context* were significantly related to the tendency to withhold requests. For example, younger employees were significantly more likely to report that they withheld requests due to perceived lack of normative appropriateness. In terms of request context, supervisor supportiveness was the most dominant factor and highly correlated with co-worker supportiveness. Together this suggests that the perceived normative appropriateness of requesting accommodation was more a function of general relationship quality than organization's resources. Moreover, a supportive relationship with one's supervisor may influence the extent of co-worker supportiveness. Only one study variable, sex, was shown to correlate with both supervisor and coworker supportiveness—women reported slightly higher quality relationships.

Just over half of the respondents reported that they had withheld a request for a needed accommodation at least once within the last year due to perceived lack of normative appropriateness. Roughly one quarter had done so within the last month. Yet, while withholding requests is common, the frequency is uneven and much less likely when supportive relationships are formed.

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the RIT College of Science and the Center for Professional Development, to identify and implement best teaching practices for deaf and hard-of-hearing students. The goals of the project are to 1) conduct a series of experiential workshops and individualized coaching activities, 2) use the workshops and individualized activities to identify challenges and best teaching practices, linking practice to the principles of Universal Design for Instruction, 3) package the materials and activities in a variety of portable formats designed to motivate and actively engage faculty at other postsecondary institutions, 4) field-test the products, 5) disseminate and deliver the products nationally, and 6) establish an administrative model that will enable core project functions to be maintained beyond the funding period, both at RIT and at other postsecondary institutions. For more information on the project, contact Foster at *SBFNIS@RIT.EDU.*

CART in the Classroom: How to Make Realtime Captioning Work for You

June 26, 2001

Duane Smith
National Court Reporters Association
Pat Graves

Introduction

Communication Access Realtime Translation (CART) is a word-for-word speech-to-text interpreting service for people with a hearing loss or who would otherwise benefit from this accommodation. Unlike computerized notetaking or abbreviation systems, which summarize information for the consumer, CART provides a complete translation of all spoken words and environmental sounds, empowering consumers to decide for themselves what information is important to them. Section 36.303(b)(1) of the Americans with Disabilities Act specifically recognizes CART as an assistive technology that affords effective communication access.

A CART provider uses a steno machine, notebook computer, and realtime software to render instant speech-to-text translation on a computer monitor or other display for the benefit of an individual consumer or larger group in a number of settings: classrooms; business, government, and educational functions; courtrooms; and religious, civic, cultural, recreation, and entertainment events. In addition, a CART provider is sensitive to the varying needs of consumers and has had training in conveying a speaker's message, complete with environmental cues.

The demand for CART has grown at a steady pace in recent years in almost all arenas. However, the greatest growth has taken place in the educational setting, from elementary to graduate school, as this technology has gained greater notoriety among educators, disability services coordinators, and students with hearing loss as a useful method for participating fully in the classroom. Several key factors play a role in determining the effectiveness of this service: the competence of the CART provider, the environment in which CART is provided, and the ability of the CART provider, student, instructor, and coordinator of services to work together.

CART Benefits

In the 1999 paper "Real-Time Speech-to-Text Services," the authors, members of the National Task Force on Quality of Services in the Postsecondary Education of Deaf and Hard-of-Hearing Students, referenced a 1988 study at the Rochester Institute of Technology of students who are deaf and hard-of hearing. When surveyed about CART, the students responded favorably. The authors state that "A majority of the students reported that they understood more from the steno-based text display than from interpreting" (Stinson et al., 1999, p. 12).

The Task Force noted several other advantages to the steno-based CART system: 1) CART provides a verbatim record of the class, capturing every word spoken; 2) a single CART provider

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can cover a two-hour class with a brief break; and 3) the steno machine is silent (Stinson et al., 1999, p. 21). Because CART gives students with hearing loss a complete record of what is said in the classroom, several other advantages to this communication access tool become readily apparent:

Flexibility. CART can be used in a variety of settings, whether one-on-one with a single student reading off of the CART provider's laptop computer screen, in a small group with the text appearing on a television monitor, or even in a much larger setting with the CART provider's realtime text projected to a large screen for everyone in the lecture to read.

Independent learning. With the provision of CART, the responsibility for a student's education rests with the student. Rather than relying on notes provided by others, the student will have a verbatim record of the class or discussion from which to determine what is or is not important based upon the student's understanding of the material presented. In addition, students can have the text file fed through a version of litigation-support software as the CART provider realtimes the class. The student can then use the highlight or annotate features of the software to pick out what he or she wants to retain. Thus, the student has the choice of obtaining the verbatim record of the class or only those portions that he or she deems important. As Rachel Arfa (2000), who used CART as an undergraduate at the University of Michigan, explains, "With realtime captioning, I was able to form my own opinions of the subject matter and receive the information firsthand, rather than second, third or fourth hand, since CART takes every sentence that is being said."

Full participation. Because the provision of CART services is in real time, the student with hearing loss has the opportunity to participate in a classroom setting just like any other student. Andy Nelson (2000), who used CART at the University of Washington, says, "Realtime captioning allowed me to get everything the professor says in class, word for word, as well as comments or questions students have during the lecture. This enabled me to actively participate in discussions and lectures, something I had never ever been able to do before." Joan Andrews (2000), a CART consumer while in college, offers another example: "Realtime professionals also can include brief descriptions that provide information about the mood of the person speaking — excited, despairing, angry, heated, placating; signals that the hearing students access easily and which often guide them in choosing their responses to the dialogue taking place. These bits of information play a vital role in effective classroom participation."

Equal access. "CART allowed me for the first time in my entire academic career to follow classroom discussions, participate in classroom discussions, and take my own notes," says Carolyn Ginsburg (2000), who used CART while earning her MBA from Columbia University. "What an incredible experience this was. It was very liberating, made me finally feel equal to my peers in the classroom, gave me equal access to information, and gave me more confidence to express my opinions and answers." Paul Hartley (2000), currently a student at Emory University, offers a similar opinion: "Being at the same level as any other student is the major and most important benefit of CART services. I get the same information, hear the same lectures verbatim, feel more a part of the class, and hear interesting anecdotes or a professor's corny jokes."

The provision of CART services also offers some benefits to the instructor. For example, verbatim lectures may give the college professor an additional tool for preparing tests or integrating information into a research study. Further, "Some instructors welcome the transcripts as a way of tightening their lectures and reviewing their students' questions and comments. If the instructor chooses, he or she should be at liberty to share them with hearing members of the class also. The transcripts can be of value also in tutoring deaf and hard-of-hearing students, enabling tutors to organize tutoring sessions in close accord with course content" (Stinson et al., 1999, p. 7-8).

The Competent CART Provider

The utility of CART services for the student with hearing loss depends a great deal on the skills of the CART provider. The National Court Reporters Association has been certifying court reporters for more than 75 years, and NCRA is currently developing a certification specifically for CART providers. Until this objective measure of the CART provider's ability is in place, how can you define a competent CART provider?

NCRA's CART Task Force considers the Registered Professional Reporter (RPR) a requisite for a qualified CART provider. The RPR certifies the entry-level reporter's ability to provide a verbatim record at speeds ranging from 180-225 words per minute with a minimum accuracy of 95 percent ("How to Locate," 2001). The Task Force also recommends the attainment of the Certified Realtime Reporter designation. The CRR has proven his or her ability to write realtime at variable speeds ranging from 180-200 words per minute with a minimum accuracy of 96 percent. *The CART Provider's Manual* (2001), published by NCRA, offers some additional factors to consider:

Sensitivity. The CART provider has general knowledge about Deaf culture and understands that the preferred communication mode of a person with hearing loss differs depending on whether the individual identifies him or herself as Deaf, deaf, late-deafened, or hard-of-hearing. A CART provider acquires training in communication techniques through court reporting association seminars, disability agencies, sign language courses, etc.

Staying in role. The CART provider's role is to facilitate communication. A CART provider declines any invitation or suggestion to comment, interject, advise, respond to inquiries, or in any way become involved in the proceedings outside the role of CART provider.

Confidentiality. Courtesy and discretion are required of the CART provider at all times. A casual word or action may betray a consumer's confidences or violate a client's privacy.

Professional development. The CART provider keeps abreast of current trends, laws, literature, and technological advances relating to the provision of CART service.

Preparation. The CART provider must make every effort to ensure an accurate job dictionary for the terminology to be used in each class.

Realtime writing. The CART provider writes conflict free, includes punctuation, and sustains accuracy for long periods of time.

Software/computer knowledge. The CART provider must operate a computer-aided transcription program and understand its realtime translation and display functions. The competent

CART provider knows how to troubleshoot and solve hardware, software, and other technical problems. In order to meet consumer preferences, the CART provider must know how to activate upper/lowercase, colored backgrounds, enlarged text, and other display options. When appropriate, the CART provider must be able to furnish the computer file of the session text as requested.

Language comprehension. Knowledge of grammar, punctuation, sentence structure, spelling, vocabulary, high-frequency colloquialisms, and slang is crucial. The CART provider must listen for continuity, sense, and detail of proceedings, anticipating and preventing errors in translation.

CART Environments

CART services can prove effective in almost any educational environment, from grade school to graduate school. In particular, "Today, steno-based systems rank as an effective support service for large numbers of deaf and hard-of-hearing students in mainstream college environments throughout the country" (Stinson et al., 1999, p. 5).

Why is the steno-based CART system gaining popularity? Much of it goes back to the comments from CART consumers regarding independent learning, full participation, and equal access. As noted in "Auxiliary Aids and Services for Postsecondary Students With Disabilities," published by the Department of Justice's Office of Civil Rights (1998), schools not only must provide auxiliary aids and services in a timely manner, but they must ensure that students with disabilities can participate effectively. And the definition for effectiveness? "No aid or service will be useful unless it is successful in equalizing the opportunity for a particular student with a disability to participate in the education program or activity."

Keep in mind, however, that generally CART consumers are individuals who have developed a hearing loss postlingually, or rather after the acquisition of language. In addition, there is no set age at which a child can begin to make use of this service: "Always remember that each individual case is unique -- there are no hard-and-fast rules on the age level of a student for which realtime translation is suited" (Brentano et al., 2000, p. 22).

Before implementing CART in an educational environment, the most important consideration, of course, is the student's preference regarding a method for communication access. Other factors are prior experience and satisfaction with realtime speech-to-text translation in the classroom, the student's ability or willingness to participate in discussions and to ask questions, and the level of reading proficiency (Stinson et al., 1999, p. 23).

Working Together

The success of CART in the classroom setting depends not only on the provider's skill level, but also on the ability of the CART provider to work effectively with instructors and the coordinator of services to ensure that the student with hearing loss receives the best service possible. Following are several considerations that can help to ensure an effective working arrangement to the benefit of the student with hearing loss:

Control of the classroom. The CART provider is in the classroom with the sole purpose of providing communication access for the student who is hard-of-hearing. To ensure an effective realtime translation, students should speak one at a time. "Noisy" conditions can have an adverse effect on the production of accurate text by the CART provider (Stinson et al., 1999, p 9). The responsibility for controlling the classroom lies with the instructor, who must maintain an orderly discussion to allow for participation by the CART consumer. The instructor may need to restate a student's comments to ensure understanding.

Preparation. "The reporter will work with the instructor for each assigned class to assure that all the technical terminology for that particular class will be provided in advance so that it can be entered into the reporter's computer dictionary" (Brentano et al., 2000, p. 9). This preparation, with the instructor's assistance, allows for a more accurate translation of the spoken word. The CART provider should receive copies of all textbooks and other class materials from which to prepare.

If possible, this preparation also includes a meeting between the CART provider, student, instructor, and coordinator of services before the start of the school year. At this time all involved parties can ask questions regarding requirements or concerns. In addition, "This will allow the reporter an opportunity to view the classroom's physical setup and to work out with the disability coordinator, instructor, and student the best seating and sight lines available for all concerned" (Brentano et al., 2000, p. 22).

Laying out the ground rules. Discuss during the orientation meeting what will be expected of the CART provider. What classes will require CART? How long are the classes? Will the CART provider be following the student to different classrooms? Who is entitled to receive a copy of the notes? What form will the notes for a class take: paper or disk? When will the student receive the notes? Will the CART provider have time to edit the notes? Will the instructor also receive a copy of the class notes?

How will the CART provider contact the instructor or disability services coordinator or vice versa? For example, "If a teacher or professor is canceling class or is giving a test for which the reporter's services are not required, sufficient notice should be given if for nothing other than common courtesy" (Brentano et al., 2000, p. 25). A policy should also be established for when the student is unable to attend class.

Think communication. When possible, the instructor should write announcements, assignments, proper names, technical vocabulary, formulas, equations, and foreign terms on the blackboard (Battat, 1998). In addition, the instructor should not "talk to the blackboard" and have his or her back turned to the class all the time. And when using overheads or referencing material on the blackboard, the instructor should be specific when explaining concepts, formulas, or equations. For example, in a math class rather than pointing to the blackboard and saying, "You add this and this and get that," the instructor should say, "You add 5 and 4 and you get 9."

Just as the primary role of the realtime reporter in the classroom is to provide communication access, it is communication between the CART provider, student, instructor, and coordinator of disability services that will prove critical to the successful provision of this service.

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Background

The faculty and staff of the North Dakota Center for Persons with Disabilities (NDCPD) at Minot State University (Minot, North Dakota) have developed a Realtime Remote Online Captioning System. This system (RROCS) provides realtime captioning via the Internet to rural and isolated classrooms. Initial field testing suggests that the RROCS has the potential for improving access to general curriculum for students with a variety of hearing, language, learning, and attention deficit impairments.

The need for options. Students who have access to a variety of instructional accommodations have the best chance of receiving instruction that meets their individual needs. The accommodations generally used for students with hearing impairments have been categorized into amplifications and strategies for converting speech-to-text or speech-to-sign. Accommodations for converting spoken material into alternate formats currently rely on a trained and available cadre of sign interpreters, note takers, and realtime captionists. Unfortunately, rural communities rarely have access to the person-power required to make even standard accommodations available.

Frontier states such as North Dakota, Wyoming, South Dakota, and Idaho have attempted to respond to these service shortages by increasing the number of trained interpreters. Unfortunately, the distances between schools and communities in such locations precludes a person-centered solution. Further, use of speech-to-text translation software, while entertaining to tinker with, is as of yet inadequate for the dynamic environment of the classroom.

Realtime Remote Online Captioning System

The Realtime Remote Online Captioning System (RROCS) developed by Fifield and his colleagues at the North Dakota Center for Persons with Disabilities (http://ndcpd.org) provides a

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http://www.rit.edu/~techsym

tool for delivering captioning services to rural and isolated locations. Audio from the teacher and the classroom is captured via a lapel or handheld microphone and transmitted to a classroom computer running the RROCS software. The software digitizes the audio and transmits it via the Internet to an off-site captionist who is also running the RROCS software. The software plays the classroom audio for the captionist who transcribes it either directly into the RROCS or by using a commercial transcription program such as GlobalCat. The transcribed text is transmitted back to the classroom where it is displayed for the student. The transcript is also posted to a password protected web site for later retrieval or emailed to the teacher and/or student.

The RROCS features a scheduling server that allows a large number of classrooms to schedule a variety of concurrent captioning events and order note taking or verbatim captioning. The scheduling server accommodates differences in time zones, monitors the status of the connection, tracks billing information, and manages the start-up connections for both classrooms and captionists. Likewise, the server plays host to a number of captionists and note takers who are matched up with scheduled classroom events.

The RROCS provides a means of delivering just-in-time classroom captioning services virtually anywhere there is a telephone or Internet connection. The system has a turnaround time of approximately three seconds, depending on bandwidth limitations. It has been successfully used with both high speed Internet connections and medium speed telephone modems.

Equipment. The RROCS has three pieces of software: a classroom client, a captionist client, and the scheduling server. The software operates in Windows 98, NT, 2000, or ME. Because of the audio compression that is required, it is recommended that classroom PCs have a clock speed of at least 600 MHz and 128 Kb of memory. In practice, any microphone system that can adequately capture classroom audio and connect to the computer's sound card should be adequate. A wireless Shure lapel microphone connected to a separate mixer was used in the field test trials.

Costs. There are equipment and personnel costs associated with delivering RROCS. Equipment costs are dependent on how elaborate a microphone system is necessary for the classroom. During the field testing of RROCS, the decision was made to purchase wireless microphones that would not be sensitive to environmental noise. The Shure wireless microphone systems used during field testing cost approximately $800 each. The classroom computers used during field testing were off-the-shelf models costing approximately $1200.

Personnel costs associated with RROCS are no different than more conventional live captioning services. During field testing, captionists who had training as court-reporters and who provided their own steno machines were paid between $35 and $50 per classroom session, depending on their experience. Note takers, who were not providing verbatim transcripts, were paid $8 per hour. In most cases, the captionists and note takers were working from their homes dialing into a local Internet Service Provider.

Availability. Captioning services using RROCS are currently available through the North Dakota Center for Persons with Disabilities at Minot State University. The service can be delivered virtually anywhere there is a telephone or Internet portal. With a modest investment in equipment, either note taking or verbatim captioning can be delivered via the RROCS at any time and for any duration. Once equipment is purchased, customers only pay for the captioning services they access.

Case Studies

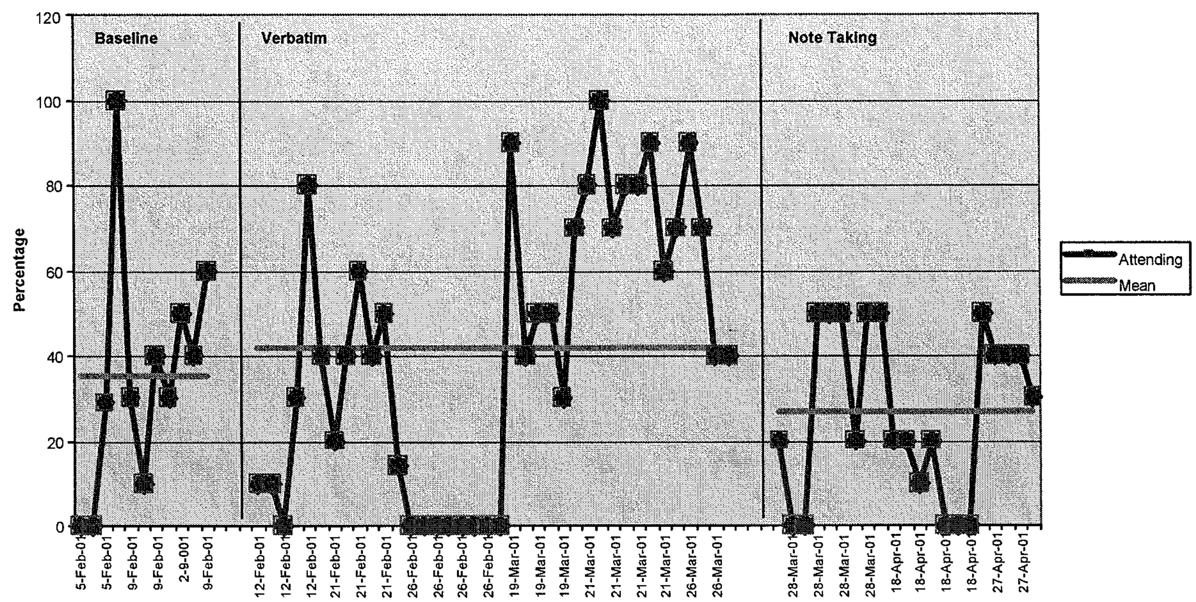
Weekly tests of the RROCS were made in both laboratory and classroom settings during the initial development of the RROCS. This process led to the identification of many design challenges to make the system easy to use, non-intrusive, and robust. More recently, the system has been used to caption workshops, conferences, and committee meetings as well as classroom presentations.

Participating subjects were observed during instructional sessions in each of the implementation classrooms to determine if they were watching the captioned text being displayed on the computer monitor. Every thirty seconds, the observer recorded a code corresponding to the observed behavior (e.g., not academically engaged, academically engaged, or viewing the text). For each interval in which the subject was not viewing the text display, project staff noted the alternative behavior in which the individual was engaged. For each five minute observation session, project staff recorded the percentages of intervals during which each subject was watching the text display.

Subject One. Subject One is a 40 year old undergraduate student at Minot State University. Subject One's hearing loss is described as moderate in both ears. No reading scores were available for this subject.

Subject One received captioning and note taking services in an introductory course for special education. There were 65 students enrolled in this class. The course format included lectures, class discussions, and small group activities. The instructor regularly used overheads and handouts. The subject sat in the front row of the class and viewed the text display on a computer monitor which was positioned directly in front of her. Figure A provides a graph of the percentage of intervals Subject One watched the realtime transcript during each of the experimental conditions.

Figure A: Subject 1

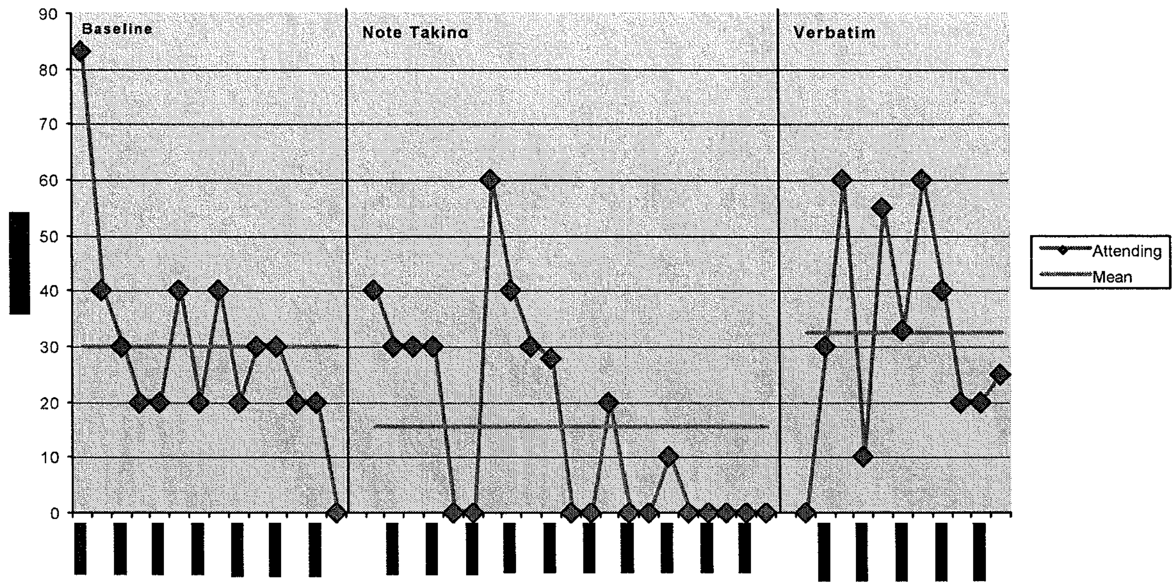


The baseline phase recorded the intervals in which the subject was observing the instructor. During the verbatim captioning phase, the average number of intervals during which the subject observed the text was higher than the corresponding behavior during baseline. Visual inspection of the verbatim phase suggests a general upward trend in the percentage of time being spent watching the captioned text. In contrast, the average number of intervals during which the subject attended to the note taking text was lower than during verbatim captioning. This average was also lower than the baseline conditio n.

Subject Two. Subject Two is an eleven year old student at a middle school in Minot, North Dakota. Subject Two uses hearing aids and an FM system. His disability is characterized as a severe to profound bilateral hearing loss. Results from reading tests indicated that Subject Two's letter-word identification and passage comprehension skills are above average for hearing students in the same grade. This subject exhibited a particular strength in his ability to sound out unfamiliar words.

Subject Two received note taking services and verbatim captioning in a sixth grade science class. There were 24 students in this class. The subject was seated in the middle of the front row near the teacher and an overhead projector. The text was displayed on a computer monitor placed slightly to the subject's left. Class format consisted of lectures, discussions, and lab demonstrations. During lab demonstrations, the teacher was on the subject's far right. Students recorded answers in a laboratory workbook as the teacher completed experimental procedures. Figure B provides a graph of the number of intervals Subject Three was observed attending to the realtime transcript during the various experimental conditions.

Figure B: Subject 2



During the baseline phase, Subject Two attended to the instructor an average of 30% of the observation intervals. When note taking services were provided, his attention to the transcribed text was only about half of what the comparable behavior was during baseline. However, when verbatim text was provided, his attending was slightly higher than during baseline.

<u>Subject Three</u>. Subject Three is a fourteen year old student at a middle school in Minot, North Dakota who uses hearing aids. His disability is characterized as a sloping mild to profound hearing loss in his right ear and a severe to profound hearing loss in his left ear. Results from reading tests indicated that Subject Two's letter-word identification and passage comprehension skills are below average when compared to hearing students in the same grade.

Subject Three received note taking services in an eighth grade social studies class for one week. Time did not allow for the provision of verbatim transcriptions during this phase of the classroom trials. There were 22 students in this class. The subject was seated in the back of the classroom. The computer monitor on which the text was displayed was positioned on an empty desk in front of the student. Class activities consisted of lectures and discussions. Overheads, handouts, and media presentations were frequently used by the classroom teacher. Students recorded notes on an outline form prepared by the teacher. Figure C provides a graph of the percentage of intervals Subject Three attended to the realtime transcript.

Figure C: Subject 3

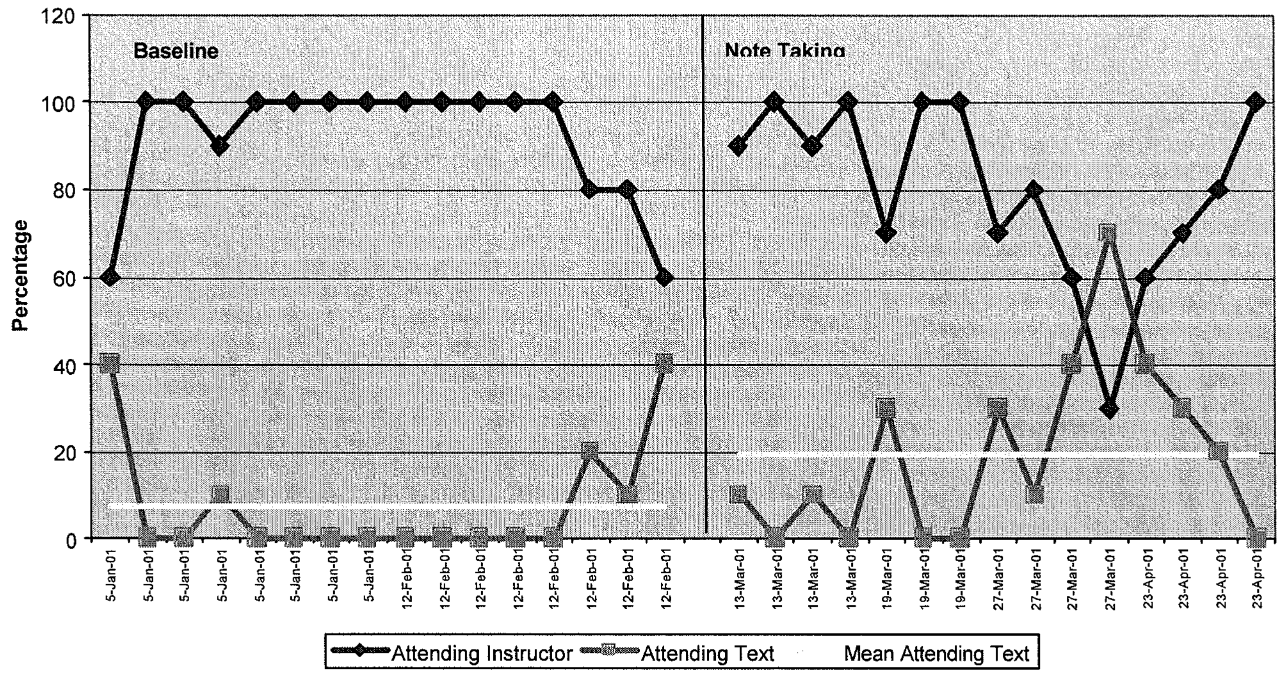


Figure C displays two behaviors, attending to the text *and* attending to the instructor. Because of the layout of the computer monitor in this classroom, it was not easy for the student to attend to both the instructor and the captioned text, they were mutually incompatible behaviors. Thus, as one went up, the other had to go down. During baseline, the student attended well to the instructor or to other instructional stimuli. During the note taking phase, the average number of intervals spent attending to the captioned material went up while the number of intervals spent watching the teacher dropped correspondingly. More than anything else, this classroom trial illustrates the difficulty in integrating the captioning system, whether verbatim or note taking, into the instructional environment.

Implementation Interviews

Interviews were conducted with all three subjects and their teachers to gather additional qualitative information individual preferences. The following table summarizes the content of the interviews.

Subject 1

	Note Taking	Verbatim Captioning	Transcripts
Subject 1	The information is too incomplete. Because the text is so limited, too much information is missed. Notes are not thorough enough to gain adequate access to classroom information.	Word for word captioning is extremely beneficial, especially in classrooms in which visuals and handouts are not used. Verbatim captioning allows students with hearing impairments to totally engage in classroom activities.	Verbatim notes are very thorough and greatly enhance handwritten notes.
Instructor	This service seems to be less accurate. Note taking results in missing large chunks of information. The student responded unfavorably to this service.	Captioning is an accurate and complete system. The student greatly benefited from this format.	Verbatim notes provide missed information and enhancing facts and examples.

Subject 2

	Note Taking	Verbatim Captioning	Transcripts
Subject 2	The notes were somewhat helpful for getting information that was missed through speech reading.	Was not provided	The notes were helpful in studying for tests.
Instructor	The text display not only helped the student with hearing impairments, but was also beneficial for students with poor listening skills.	Was not provided	The student with hearing impairments really benefitted when he used the transcript to study after class.

Support Service Provider	Because all of the students with hearing impairments receive copies of the teacher's lecture notes, the note taking format does not provide any additional information. The verbatim system would probably be more beneficial. Other students, however, were watching the text. The reinforcement in print is beneficial for many students. It increases reading speed and helps improve comprehension by providing information through an additional mode. It is also helpful to see difficult words in print. Students can see the spelling and connect the word with the auditory signal.	Was not provided	Were not accessed

Subject 3

	Note Taking	Verbatim Captioning	Transcripts
Subject 3	The notes were not complete enough, but they did help when what the teacher said was missed.	Having all of the words on the screen was helpful for knowing what was going on in class and for helping to feel more a part of the class.	Were not accessed
Instructor	Because the student already had a copy of the notes on a handout and overhead (as required on his IEP), note taking did not add any new information.	Captioning is much more meaningful and beneficial for the student. Captioning captures all of the examples and stories which are presented to enhance understanding. The student's quiz scores improved after he was exposed to captioning.	Were not accessed

Summary

The Remote Realtime Online Captioning System provides a cost-effective, instructionally viable means of accommodating students with a range of hearing, language, learning, and attention deficit impairments. Data from several classroom trials suggest that the system is amenable to variety of different instructional environments. As any computer program that uses the Internet to stream media, it is subject shortcomings associated with limited bandwidth or inadequate connectivity. However it appears to be robust enough to work in most classrooms with a minimum of teacher intervention.

Students and instructors who participated in the initial field testing have indicated a preference for verbatim captioning over note taking. Observational data confirm that students attend to the transcription text more when it is verbatim rather than note taking. Whether or not this preference has instructional implications is unclear at this point. During verbatim captioning the text can be scrolling off the monitor at a rate of between 100 and 200 words per minute requiring the student to be constantly engaged, especially if there are other things going on associated with the teacher's instruction (e.g., overheads, chalkboard presentation, demonstrations, etc.).

Further investigations are underway to determine to what degree captioning increases the comprehension of participating students. Thompson (1999) reported significant gains for a graduate student with a hearing impairment when captioning was provided. Whether or not this finding is observed in middle school, secondary, and post secondary students has yet to be determined.

Ultimately, the degree to which types of captioning (verbatim or note taking) and what delivery mechanisms (online or live) are most effective may in fact be moot. Much like curb-cuts or ramps, schools need to provide access to instruction. Realtime Remote Online Captioning provides one means for rural and isolated schools and colleges to meet this requirement in a cost-effective and timely fashion.

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ESTABLISHING A REALTIME CAPTIONING PROGRAM: DESIGNED TO MEET THE NEEDS OF 28 MILLION DEAF AND HEARING IMPAIRED AMERICANS

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With the ability to provide open access at the local, regional, and statewide levels, community colleges are proving that they are truly the people's college. By revising existing programs in a short period of time to meet the needs of 28 million deaf and hearing impaired Americans, we are again proving that we can provide qualified graduates for new jobs demanded by the work force.

Because West Kentucky Community and Technical College has the only court reporter program in the state that has been approved by the National Court Reporting Association, it was only natural that we could make the necessary revisions to take us to the CART level. Our decision to open the program to everyone in the entire state expanded the idea of open access to the community college from a local or regional perspective to a statewide perspective.

There are 28 million deaf and hearing impaired Americans. A broadcast Captioning & Communication Access Realtime Translation Program (CART) was established to train qualified broadcast captioners and CART providers to meet the requirements of the Telecommunications Act of 1996. The CART program was designed in a distance learning format to allow students from all across Kentucky to participate.

We were fortunate because we had an accredited court reporting program; however, from the initial planning phase through revising

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existing courses and developing new courses, it still required a 2-year timeline. Some key factors in the process were as follows:

- **Instructors required additional training.**
- **State-of-the art equipment had to be identified and purchased.**
- **A marketing campaign was designed and implemented.**
- **Curriculum revisions had to be submitted to and reviewed by local and state curriculum committees.**
- **A Congressional Award enabled us to develop and implement the necessary changes in order to get the program up and running in record time.**

The CART Program was established, and the college has enrolled its first class. In another year we will be graduating students to fill good paying jobs as qualified broadcast captioners and CART providers. This will enable Kentucky to meet the requirements of the 1996 Telecommunications Act that requires trained providers for various media events. Partner colleges will be recruited to assist in the process of gearing up to provide satellite centers for hands-on training.

It is imperative that adequate funding is in place, and that personnel are identified who have the skills that—with additional training—can be transitioned to the new curriculum. It is imperative that a qualified support staff be available for the distance learning aspect. Equally important is the development and implementation of an appropriate marketing and recruitment campaign.

College Students' Perceptions of the C-Print Speech-to-Text Transcription System

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C-Print is a real-time speech-to-text transcription system used as a support service with deaf students in mainstreamed classes. Questionnaires were administered to 36 college students in 32 courses in which the C-Print system was used in addition to interpreting and note taking. Twenty-two of these students were also interviewed. Questionnaire items included student ratings of lecture comprehension. Student ratings indicated good comprehension with C-Print, and the mean rating was significantly higher than that for understanding of the interpreter. Students also rated the hard copy printout provided by C-Print as helpful, and they reported that they used these notes more frequently than the handwritten notes from a paid student note taker. Interview results were consistent with those for the questionnaire. Questionnaire and interview responses regarding use of C-Print as the only support service indicated that this arrangement would be acceptable to many students, but not to others. Communication characteristics were related to responses to the questionnaire. Students who were relatively proficient in reading and writing English, and in speech-reading, responded more favorably to C-Print.

Within the past few decades, schools have witnessed a dramatic increase in the number of deaf and hard-of-hearing students educated alongside hearing students at both secondary and postsecondary levels (Moores, 1992; Rawlings, Karchmer, & DeCaro, 1988; Schildroth & Hotto, 1994). A major concern for these students is the adequacy of classroom communication, and the communication difficulties of deaf students in mainstream classes are well documented (Osguthorpe, Long, & Ellsworth, 1980; Stinson, Liu, Saur, & Long, 1996). Even when an interpreter and additional support services are provided, students still experience communication difficulties, such as understanding the teacher and participating in class discussions and activities (Kluwin & Stinson, 1993). For example, one problem is the ability to understand hearing classmates. Many hard-of-hearing students and some deaf students use Frequency Modulation (FM) systems to supplement their lipreading of the teacher. Usually the teacher wears the FM microphone. When the students' hearing aids are switched to receive the FM input, they generally cannot hear their classmates' comments.

In response to these difficulties, and also in response to the recognized value of printed information, alternative means of support for mainstreamed deaf and hard-of-hearing students have been developed in the form of real-time speech-to-text transcription systems (Stuckless & Carrol, 1994). The first to be developed was a stenographic-based system in which the code produced by the stenographer was converted by computer into a real-time display of English text (Stinson, Stuckless, Henderson, & Miller, 1988). More recently, with the development of laptop computers, computer-assisted note taking has also been used as a support. In these systems, the support person types on

Victoria S. Everhart is now at the New Mexico School for the Deaf; Pamela J. Francis is now at the Northeast Technical Assistance Center. This study was supported in part by Grant 180J3011 from the Office of Special Education Programs of the U.S. Department of Education. "C-Print" is a registered trademark that belongs to the Rochester Institute of Technology. Correspondence should be sent to Lisa B. Elliot, National Technical Institute for the Deaf, Rochester Institute of Technology, 96 Lomb Memorial Dr., Rochester, NY 14623-5604 (e-mail: lbenrd@rit.edu).

a standard keyboard (Cuddihy, Fisher, Gordon, & Shumaker, 1994; James & Hammersley, 1994; Stinson & Stuckless, 1998; Youdelman & Messerly, 1996). One of these systems has been called C-Print in recognition of the system's display of print ("C" sounds like "see") and the computer basis of the system. In the past 15 years, the use of these systems to support students has increased steadily (Stinson et al., 1999).

It is important to evaluate these systems to determine their educational effectiveness and also their limitations. We report here a study of college students' perceptions of C-Print as a support service. This study addressed four factors related to the use of C-Print: (1) the real-time text display, (2) the hard copy printout of the text provided to students after class (C-Print notes), (3) the effectiveness of the C-Print system without other support services, and (4) individual differences in student responses to C-Print. We first provide a description of the C-Print system before discussing these four factors.

Description of C-Print

As with other computer-assisted note-taking systems, C-Print uses standard laptop computers and word processing software. However, C-Print uses additional technology and training, which permits captionists to more fully capture the lecture. Captionists are trained to use phonetics-based abbreviation software that allows for the transformation of an abbreviation into a full word on the computer screen. In addition, captionists learn strategies for listening actively, for eliminating redundancies, for identifying important points, and for condensing and organizing information (Stinson & McKee, 2000). In comparison to stenography training (usually 2–3 years), C-Print training is relatively short (about 6 weeks). Furthermore, equipment costs for C-Print ($3,500) are less than those for stenographers ($7,000), as is the salary requirement for the captionist (approximately $18 vs. $100 per hour for stenographers) (National Court Reporters Foundation, 1995; Stinson et al., 1999).

The captionist, using a computerized abbreviation system, types the words of the teacher and students as they are being spoken. The system provides a real-time display that the student can read on a laptop computer or television monitor. The text display for the message appears approximately 3 seconds after the words are spoken and remains on the screen for approximately 1 minute. This provides students far more time to consider these words than if they were using an interpreter or lipreading a speaker. In addition, the text files are saved and may be edited after class. These edited notes can be used by students, tutors, and instructors after class by reading them on a monitor or from a printed copy. The system cannot provide word-for-word transcription because it cannot keep up with the speed of speech (approximately 150 words per minute). However, the system does provide for capturing almost all of the meaning of the lecture (Stinson, McKee, & Elliot, 2000). Although the stenographer's notes are verbatim and more detailed, C-Print notes contain the important information in a more condensed format. Consequently, C-Print reduces the number of pages of notes. Students seem to find these C-Print notes easy to study because they feel that the notes contain detailed information about class proceedings and course content (Elliot, Foster, Stinson, & Colwell, 1998).

Real-Time Text Display

The amount of classroom discourse that the C-Print system captures was investigated in an analysis that compared six transcripts produced by a C-Print captionist with verbatim transcripts of teachers' lectures. This comparison found that the mean percentage of idea units captured by the C-Print captionist was 65% and that the mean percentage of important idea units (as rated by three judges) captured by C-Print was 83% (Stinson & McKee, 2000). These findings can be contrasted to those for a stenographic system. Real-time stenographic systems capture virtually every word spoken by the teacher (Stinson et al., 1988).

These findings raise the question of the extent to which students would regard the information provided by C-Print in the classroom as easy to understand and comprehensive. A previous investigation by Stinson et al. (1988) evaluated the use of a steno-based support service in the classroom. Questionnaires were administered to 121 deaf and hard-of-hearing students at the National Technical Institute for the Deaf (NTID) served by the steno-based service. Students reported that they understood significantly more lecture information with the steno system than with the interpreter. The first question of this study was whether students would respond favorably to the real-time text display of information provided by C-Print.

Hard Copy Printout of C-Print Text as Notes

A major concern of deaf and hard-of-hearing college students is that they have high quality notes for study after class. If the student relies on interpreting services, lipreading the teacher, or a real-time text display, it is often difficult to simultaneously focus on this information and on taking good notes (Hastings et al., 1997). In view of this difficulty, educators, such as Saur (1992), have stated that note taking, when a designated person in the class takes notes, is an essential support for most deaf and hard-of-hearing college students. These notes provide a permanent record that the student can review after class in order to remember the relevant information (Saur, 1992). Note taking is the most frequently used support service for deaf and hard-of-hearing students (Lewis, Farris, & Greene, 1994).

Despite the popularity of note taking, Hastings et al. (1997) and Saur (1992) describe several limitations, including variations in the quality of notes. For example, notes from student volunteers may exclude important information because the student taking notes already knows the information or does not value its importance. Paid note takers may produce better notes. However, all handwritten notes have limitations. They may be messy or disorganized and must include considerable summarization, because note takers cannot write nearly as rapidly as professors can talk.

Text produced by a real-time transcription system in class and distributed to students as a computer text file or as a printout are essentially a verbatim copy of what was said in class. This printout is likely to be considerably more detailed than handwritten notes when a computer-assisted note-taking system, such as C-Print, is used. Previous research on real-time transcription systems suggests that students prefer notes generated by real-time systems rather than handwritten notes. For example, Stinson et al. (1988) found that students perceived the printout produced by the real-time graphic display steno system as more helpful than notes provided by paid student note takers. The second question for this study was how students perceive the printout produced with the C-Print system.

C-Print Without Other Support Services

Although a speech-to-text system is most economical when it is the only support service in a given course, it may be used in addition to other support services, such as interpreting. The Stinson et al. (1988) study included a question about preference among various support services including interpreting, steno system display on TV, note taking, steno system printout, and tutoring. Results indicated that students had a favorable opinion of the steno system relative to other support services. Overall, 62% of the students selected either the real-time display or the printout of the text as their most preferred support service, whereas 36% selected either note taking or interpreting as the single most preferred system. The frequent choices of these two services provided by the steno system suggested that the system could sometimes be used without the support of an interpreter or note taker. Students were not, however, asked directly whether they perceived that system as an appropriate support service if they used it without other support services. The third question of this study was whether students perceived this practice as appropriate.

Individual Differences in Perceptions of C-Print

Given the variations in communication preferences and learning styles of deaf and hard-of-hearing students, they likely will also offer differing favorable or unfavorable responses to specific support services, including C-Print (Kluwin & Stinson, 1993; Lang, Stinson, Kavanaugh, Liu, & Basile, 1998). For example, because C-Print provides printed English, students who are relatively proficient readers may respond more favorably than those who are less proficient. Stinson et al. (1988) considered communication preference and educational background of students who used a steno system and their preferences for interpreting, steno system display, note taking, steno system notes, and tutoring support services. The authors reported individual differences in preferences for various support services. Students who came from mainstream high school programs and who were relatively proficient in reading, writing, and speech-reading tended to prefer the steno system. On the other hand, students who came from residential or day schools for the deaf, who were relatively proficient in manual reception, but who were less proficient in auditory discrimination, speech-reading, and speech production, were likely to prefer an interpreter.

These results suggest that individual differences in student characteristics would also relate to students' favorable ratings of C-Print. The fourth question of this study was whether student characteristics were related to the ratings of C-Print.

Method

To examine college students' perceptions of the C-Print service, we employed a multimethod research strategy, an approach that has been gaining acceptance in educational research (Garrison, 1986; Howe, 1988). Use of multimethod design enables researchers to develop a deeper understanding than the use of only one methodology (Eisenhart & Borko, 1993; Howe, 1988; Howe & Eisenhart, 1990; Lagemann & Shulman, 1999). To this end, this study collected questionnaire and qualitative interview data and also used information on background and communication characteristics from NTID student records.

Participants

The participants for the questionnaire component of the study were 36 deaf or hard-of-hearing college students (17 women, 19 men). They received the C-Print support service in one of their mainstream courses at the Rochester Institute of Technology between spring quarter 1994 and fall quarter 1996. Students received the C-Print service for all class sessions in the 10-week term. All students who received the services were asked to complete questionnaires and participate in interviews. Virtually all the students who answered the questionnaire had attended mainstream high school programs (32) as opposed to separate day or residential secondary schools (4). The mean pure-tone average for the better ear was 95.12 (SD = 14.32). The students' overall grade point average was 2.85 (SD = .57) on a 4-point scale. All students who apply to NTID or receive support through NTID are asked to complete the Language Background Questionnaire (LBQ) developed at NTID and containing items related to self-perceived skill levels in several modalities (Metz, Caccamise, & Gustafson, 1997). The mean score on the LBQ item providing a self-rating of sign proficiency was 2.83 (SD = 1.11), where 1 = poor skills and 4 = high-level skills, indicating relatively good sign proficiency. Twenty-two students participated in the in-depth interview component of the study. All of these students, except one, also responded to the questionnaire described above.

Courses

Eight students served by C-Print were in business courses; 28 in liberal arts courses. Examples of courses covered by C-Print included "Foundations of Sociology" and "Social Psychology" in the College of Liberal Arts and "Financial Accounting" in the College of Business. The courses were taught by 4 different faculty members in the College of Business and 12 different faculty members in the College of Liberal Arts.

Twenty-seven of the students were in courses identified by the C-Print captionist as primarily lecture-oriented, five in discussion-oriented courses, and four in a course that had approximately equal amounts of lecture and discussion. All students had trained note takers and tutors in their courses, and all but two students had interpreting services as well as C-Print. These two students agreed to use C-Print instead of an interpreter.

Materials and Procedures

The materials and procedures for collecting the three sets of data include the following.

Questionnaire. The questionnaire included items relating to (1) the use and understanding of the real-time display, (2) the use and assistance provided by the C-Print hard copy notes, and (3) the use of C-Print as the only support service. These questionnaire items are presented in Appendix 1. All items except for one were fixed-alternative questions. Questionnaires were distributed by the C-Print captionist during a class session near the end of the term. Students completed the questionnaire independently, returned it to an office at NTID, and received $3 for their time.

Interviews. The purpose of the in-depth interview was to extend our understanding of how students perceived the effectiveness of the C-Print system and how they used it to aid learning in the mainstream classroom. Some of the information solicited during the interviews addressed the same issues as the questions included in the questionnaire (see Appendix 2). However, the interviews were open-ended and participants were encouraged to pursue their own line of reasoning. This resulted in elaboration that was not possible within the constraints of our questionnaire. The interviews lasted 30 minutes to 1 hour. Students received $10 for their participation. Interviews were conducted by two members of the research team who were proficient in sign communication (Everhart, Stinson). The students' communication skills varied. Most of the students used sign communication with or without speech, and the interviewer used sign communication and speech. A voice interpreter repeated the interviewer's and respondent's sign and voice communication into an audiotape recorder. A few students preferred to use spoken English. If these students had intelligible speech, their responses were spoken directly into the tape recorder. If their speech was judged unintelligble, the interpreter voiced the responses. Interviews were later transcribed verbatim for analysis.

Student records. Students gave the researchers permission to access their records, which are maintained in a database at NTID. Data from five tests of communication proficiency were used for this study: (1) reading comprehension subtest of the California Achievement Test (M = 10.77, SD = 1.07), (2) Michigan Test of English Proficiency (M = 81.76, SD = 12.63), (3) NTID Test of Speechreading with Sound (M = 68.60, SD = 33.55), (4) NTID Test of Speechreading Without Sound (M = 46.90, SD = 22.45), and (5) NTID Test of Simultaneous Communication Reception (M = 84.00, SD = 14.28). The first two tests are standardized achievement tests. The California Achievement Test is now called the TerraNova CAT and is distributed by CTB McGraw-Hill (2000). The Michigan Test of English Proficiency is a retired component of the Michigan English Proficiency Battery distributed by the English Language Institute at the University of Michigan (2000). The last three tests listed above were developed at NTID and are used for student advising and course placement in communication courses (see Crandall, 1978; Johnson, 1976; Subtelny, 1982). For the two speech-reading tests, students viewed a videotape of a person saying sentences (with and without sound) and then wrote out the sentences. For the simultaneous communication reception test, students viewed a videotape of a person signing and saying sentences and were then required to write out the sentences. More detailed descriptions of the tests, the scoring, and examples of test items can be found in Johnson (1976), Crandall (1978), and Subtelny (1982).

Analysis

Questionnaire. Data were summarized using descriptive statistics (e.g., frequency distributions) and standard inferential statistics (chi-square, paired t tests).

Interviews. Verbatim transcribed interviews were analyzed using content analysis techniques described by Bogdan and Biklen (1992). The transcripts were coded into three categories: (1) use and understanding of the C-Print real-time display, (2) use and assistance provided by the C-Print hard copy notes, and (3) appropriateness of C-Print as the only support service.

C-Print index and student records. To examine the relationship between perceptions of C-Print and communication characteristics of individual students, we created an index of the extent to which students responded favorably to C-Print. Scores were combined for three questions: (1) "How helpful is C-Print without the notetaker?" (range of scores: 2–4), (2) "What percentage of the lecture was understood with C-Print?" (range: 50–100), and, (3) "How much did C-Print notes help with the course?" (range: 2–4). To give responses to these questions equal weight in the index, we applied a z-score transformation to individual students' responses to each question. We then created a

C-Print "index" for each student by adding together the three z-scores for that student. This index was correlated with scores on the five communication skills tests described above.

Results

The results for both the questionnaire study and the interview study will be summarized together where appropriate. Not all students answered all questions on the questionnaire, and due to the nature of the open-ended interview, not all students interviewed answered the same questions during the interview. The results are organized according to the study's four main topics: (1) use and understanding of the C-Print real-time text display, (2) use and assistance provided by the C-Print hard copy notes, (3) appropriateness of C-Print as a stand-alone support service, and (4) relations between perceptions of C-Print and student communication characteristics.

C-Print Real-Time Display

Students were asked how much of the lecture they understood from watching the C-Print display. Students felt that C-Print made it easy to understand the teacher. Sixteen out of 25 questionnaire respondents stated that they understood between 90% and 100% of the lecture with C-Print. A majority of the interviewed students indicated that they understood almost all the lecture. According to interview responses, students felt that C-Print facilitated comprehension of the classroom discourse. For some students, C-Print significantly improved their comprehension of classroom dialogues. One student described his experience this way:

> Well, I would say that it helps a lot. And it surprised me because I never realized how much information was provided in class. Before I always thought that the teacher did not provide enough information and it was boring, but when I was using the C-Print it seemed more interesting. It makes me feel like I have been missing something in the past. Like I missed the last few years.

When producing text in real-time in the classroom, the C-Print captionist condenses what is being said. In view of this, students were questioned specifically about whether the C-Print text contained an acceptable amount of information and captured the important points in the lecture. Most students agreed that C-Print fulfilled this function. All 31 students who answered the questionnaire item pertaining to this issue agreed that the C-Print text produced by the captionist included the important points of the lecture (χ^2 [1] = 31, $p < .001$).

Students were also interviewed about the extent to which the captionist captured all the information, and the interviewer specifically pointed out that sometimes the C-Print captionist needed to summarize in order to capture the information. A few students were surprised to learn this given the quantity of text displayed. Some students felt that the information was so complete that it had a verbatim-like quality. One student commented: (for a course served by C-Print alone) "I would understand everything that is going on in that classroom at 100% because everything would be recorded." Another student responded

> Yes, I accept that it is summarized. I can hardly tell if it is summarized. It looks like she is just typing every single word that the teacher is saying. I can hardly tell that she is summarizing. When I look at the interpreter, I can tell that they are summarizing. So I can see the difference.

Some students did, however, indicate an awareness that some information was missing. In particular, several students noted that the segments of the text display that contained other students' comments could sometimes have been more complete. Students recognized that professors sometimes spoke too quickly for their comments to be typed verbatim. In addition, it was mentioned that C-Print was not capturing graphs, formulae, or other visual information. Students commented that there were times when verbatim transcription was preferable. For example, one student expressed a desire to have verbatim transcription of other students' comments or important messages from the professor:

Student: And most important things that the teacher says that it is important to know this word or sentence then the person really needs to type that down, it really needs to show up on the screen those important words.

Interviewer: So if the professor says, "This is important to know" you want that exact sentence typed in? Because you want to know that the professor said it was important, right?

Student: If the professor says something important you really want to know that, you really want to have those exact words on there or for an announcement like it is time for a test time, for final exams, you want that specific information is really important. I don't want to show up at the wrong place at the wrong time or something like that. That would be upsetting.

In regard to students' participation in class, we were interested in knowing whether students could tell, from the C-Print display, when the professor was asking a question of the entire class or a specific person. The majority of students who were interviewed said they could tell. Several commented that a question mark appeared in the text display. Others commented that they noticed a dialogue occurring between teacher and student in the display. One student, however, commented that she was not able to detect a question posed to the class by watching the display because C-Print does not use intonation to distinguish statements from questions. Other students did not pick up on questions because of the lag time associated with the real-time display. As mentioned previously, in those cases, students may have realized that a question was asked, but by the time they read the display, the time for answering the question had passed.

We also asked students how they would feel using C-Print to relay their questions to the teacher or comments to the group. For example, interviewers suggested to students that they might type a question that the C-Print captionist could voice for them, or the comments might be displayed for all to read on a TV monitor. Several students thought this strategy would work, but others were less certain, as this approach would be quite different from the current practice of having an interpreter voice their signed message.

Students were asked to consider their comprehension of class lectures with C-Print, as compared with an interpreter. The analysis of the questionnaire responses revealed that students assigned significantly higher ratings for percentage of the lecture understood with C-Print than with interpreting (paired t test, $t = -2.43$, $p < .025$). The mean percentage of lecture information understood with C-Print was 84.8 (SD = 16.5); for interpreting, it was 69.9 (SD = 28.4).

Examination of the interview data indicated that a few students felt both services were comparable. Many more students stated that they felt they understood more with C-Print. However, reasons for better comprehension of the lecture with C-Print varied by student. First, some students had limited proficiency in American Sign Language (ASL), and, thus, the interpreters were difficult to understand. Second, the interpreters' skills varied and sometimes the interpreters missed information. Third, several students commented that they felt interpreters sometimes omitted information because they condensed the message in translating it to ASL. Fourth, several students thought C-Print included more of the actual vocabulary used by the professor and that this was beneficial for test preparation and learning the course material. In regard to the issue of the extent to which C-Print and interpreters modify what the teacher says, one student commented:

> When I watch the interpreter and the teacher, I know that the interpreter is changing what the teacher is saying a lot, and I don't like that because I feel I am losing a lot. Most of the time I will ignore the interpreter and pay attention to the teacher. Some interpreters I have had a few times, and I know if they are good or not. So it depends on the interpreter.

Fifth, some students stated that they perceived the information provided by C-Print as simply more complete than that provided by an interpreter. As one student said, "I am a fifth year student. I have experienced many interpreters, and I know that I missed a lot of information. I have seen them do it. And I know that on the C-Print that all the information is there."

On the other hand, students indicated during the interviews that they recognized the limitations of having the C-Print real-time display in class, as opposed to an interpreter. Some students favored the message provided by the interpreter and thought they learned more by watching the interpreter because the interpreter captured more of the classroom activity than did C-Print. One student described her feelings this way:

> I would like to add that why I only looked at the in classroom thing for only five minutes, because the interpreter has expression and I have a better sense of what is happening in class. From the C-Print it is just kind of blank. There is nothing there. People are laughing and I don't know it, people are moving, things are happening in class and I can't realize it. And so I only watched the in class thing, the display, for five minutes.

Interpreters add a more personal touch. With an interpreter, the students watch an individual conveying the message, rather than reading text. Also, for a student without intelligible speech, participation in class may be more difficult when only the C-Print service is provided. As one student commented,

> The only problem I would see is if I don't have an interpreter—what if the student has a question? How would they ask? Or maybe the student could type the question and it appears on the screen . . . and the teacher can see the screen, and then they know what the question is.

During the interviews, students were asked to consider in which class settings C-Print was most helpful and in which settings an interpreter would be most helpful. Several students felt that C-Print would be most helpful in lecture-only classes. Some students appreciated C-Print in their discussion-based classes as well, because the C-Print notes provided a transcript of the discussion. Other students supported the idea of an interpreter for discussion-based classes. Clearly, there is no one solution to this dilemma.

As evidenced here, for certain students and in certain circumstances, one service may be more useful than another. Students expressed the opinion that C-Print and interpreting services are complementary. For example, currently, interpreters seem to better capture group discussion, whereas C-Print notes seem to better help students remember that discussion later.

C-Print Notes

An important component of the C-Print system is the hard copy printout of the C-Print text, called the C-Print notes, that is distributed to students after class. The students in the study were asked for their perceptions (1) regarding the C-Print notes relative to the handwritten notes of student note takers, (2) their use of the C-Print notes, and (3) the advantages or disadvantages of the C-Print notes.

On the questionnaire, students rated how helpful they found the C-Print notes. Due to the small number of subjects, the four rating categories were collapsed into three for analysis purposes: "helps little or none," "helps enough," and "helps very much." Almost all students (33 out of 36) rated the C-Print notes as helping enough or very much (χ^2 [2] = 15.17, $p < .01$). Twenty-four out of 34 students responded that they used the C-Print notes more than the notes from the note taker. This difference in frequency was statistically significant (χ^2 [1] = 5.76, $p < .02$). Students were hard-pressed to identify disadvantages of the C-Print notes. The few students who did criticize the notes were concerned with the length of the transcript and the amount of time needed to read the notes, the quantity of paper used for printing notes, and the lack of illustrations or other graphic information.

In the interviews, students were asked about how often they would read a set of C-Print notes. Some students did not integrate reading C-Print notes into their regular study routines. As one student remarked, "It is going to take time for us to fully adapt to C-Print." Other students made the transition to C-Print notes more easily and read the notes regularly. They reviewed the notes between 1 and 3 times for each class session.

We also asked students about specific ways that they used the C-Print notes. For the 36 students who responded to the questionnaire, 29 reported skimming the notes. Sixteen of these students reported noting unfamiliar vocabulary and ideas, and 10 reported using the notes to create their own outline. Fourteen students reported "other" uses of the notes, such as reading.

Similarly, in the interviews, students reported using the C-Print notes for study in a variety of ways: (1) skimming the text, (2) reading and rereading the text, (3) noting special vocabulary, and (4) making an additional set of personal notes. One student reported using the following strategies in studying notes:

> I just read them to see if I know the information. And I know that, know that, fine, no problem. And

> then I get to something I have not seen before, then I mark it, I mark it up. And then I continue reading, and then I go over it again to figure out what they are talking about, and try to understand everything that is going on. And then like words I never saw before or heard before, I underline. And then I write an explanation about what it means. And I use that for tests. Yes, it helps a lot. It has really pulled my grades up a lot.

These results suggest that students' study techniques might be best characterized on a continuum from passive to active approaches, based on the degree to which they manipulated the notes to fit their needs. The more passive approaches for using the C-Print notes involved only reading them. For example, several students looked at the notes only on occasion and just skimmed the notes. Many students said that they read them more thoroughly. Still other students compared C-Print notes with note taker's notes, the textbook, or their recollections of class lecture and discussion. C-Print notes were also used as an additional reference to prepare for tests and class projects.

The more active approaches for using the C-Print notes went beyond a rereading of the notes. These approaches involved reorganization of the material, identification of key points, or the writing of one's own thoughts. For example, many students said that they would read over their C-Print notes and write additional notes or questions for the professor on the margins. Several other students used the C-Print notes as the basis for writing their own notes or outline for the course.

C-Print Without Other Support Services

We asked students for their opinions regarding the use of C-Print without other support services. Students rated how helpful they thought the C-Print system would be in a hypothetical classroom situation without an interpreter or note taker present. Due to the small number of subjects, the four rating categories were collapsed into two: "help little or none" and "help enough or very much." A higher number of students (24) rated the C-Print system as helping enough or very much, as compared to the number of students (2) who rated the system as helping little or none ($\chi^2 [1] = 7.92, p < .02$).

During the interviews, students were presented two hypothetical scenarios. Students were asked to think about the acceptability of using C-Print in the classroom without an interpreter, but with a note taker, or on a "stand-alone" basis, without either an interpreter or note taker. Many students felt comfortable with the thought of no interpreter. About half of the students also felt comfortable about using C-Print without a note taker, as well as without an interpreter. Several students expressed confidence that they would understand everything if they had to rely exclusively on C-Print.

Some students indicated that they could get along with only the C-Print service because it provides complete information regarding what was discussed in class, as the following quotation reveals:

> You said one situation is you have a note taker and you have an interpreter. The other situation is that you have C-Print only, right. I would prefer the C-Print only. Yes, I would get all the information, and with an interpreter I may miss some information, and the note taker may miss some information or may only do summaries. With C-Print I am getting everything, and I can see it on the TV screen or on the laptop, and I can summarize it myself if I want to.

In contrast, a few students felt that C-Print alone was not a viable option. One student said that if he were confronted with the prospect of C-Print as a stand-alone service, he would drop the course. One concern that students raised was how they would ask questions without the aid of an interpreter.

Relationship Between Perceptions of C-Print and Communication Characteristics

This study also examined the relationship between perceptions of C-Print and communication characteristics of individual students. To examine this relationship, we correlated the index of extent that students perceived C-Print favorably with scores on five communication skills tests and three background measures (see Method section for descriptions). Table 1 presents the intercorrelations between these eight measures and the index of favorableness toward C-Print.

Relatively favorable responses to C-Print were as-

Table 1 Intercorrelations of the index of C-Print favorableness with communication skill tests and background measures

Tests and measures	*n*	*r* with C-Print index
1. Reading Comprehension Subtest, California Achievement Test	30	−.05
2. Michigan Test of English Proficiency	29	.51*
3. NTID Test of Speechreading with Sound	30	.57*
4. NTID Test of Speechreading without Sound	30	.59*
5. NTID Test of Simultaneous Communication	26	−.07
6. Puretone average	33	.23
7. Language Background Questionnaire item related to sign proficiency	30	.13
8. College grade point average	36	−.22

*$p < .01$.

sociated, at a statistically significant level, with higher scores on the Michigan Test of English Proficiency, with higher scores on the NTID Test of Speech Reading with Sound, and with higher scores on the NTID Test of Speech Reading without Sound. As shown in Table 1, the C-Print index did not correlate significantly with the other communication skill tests or background measures. Thus, preference for C-Print appears to be associated with being skilled in English and skilled in receiving spoken (e.g., English) communication.

Discussion

The results of this study indicate that many of the deaf and hard-of-hearing college students responded favorably to the form of information delivery provided by the C-Print speech-to-text transcription system. Students perceived the system as providing complete information that captured all, or almost all, the important points and details communicated in a college classroom. They also indicated that the C-Print real-time display enabled them to achieve a high level of comprehension of lecture material. Despite this level of comprehension, students did criticize certain aspects of the C-Print display—namely, lag time, captionist's difficulty in capturing other students' comments, and C-Print's inability to capture visual material, such as illustrations or mathematical formulae.

One factor in the favorable response to C-Print may be the permanence of the information on the display and in the printout. For the real-time display on the laptop that is presented during class, each row of words remains on the screen for approximately a minute. This provides students far more time to consider these words than if they were using an interpreter or lipreading a speaker. After class, students can further review the material in exactly the same wording and in much greater detail than notes from a note taker.

In general, students responded favorably to the C-Print notes. Many commented on the clarity and detail of the notes. Students recognized the benefits of the notes to themselves and to others in class. C-Print notes appear to be a versatile study tool. Students read, highlighted, and wrote on these notes. C-Print notes helped students to recall class proceedings, and students used them to study for tests and to write papers. Only a few students criticized the notes for their length and lack of graphic information.

Students generally thought that C-Print enhanced their educational experience. Some students felt that they were more confident about learning and that they could perform better when the C-Print service was provided.

The results of this study are similar to those of a study conducted during the 1980s at NTID with a steno system (Stinson et al., 1988). In the previous study and this one, deaf students assigned higher ratings of understanding to the transcription system (C-Print or steno) than to interpreting. In addition, for both studies, more students responded favorably to the hard copy text than to notes from a note taker. Why might students find the printout more helpful? Comments during interviews for this study, as well as anecdotal remarks during the previous study, suggest that the detail of the printout permits clarification of what was not understood during the lecture. Furthermore, although the content of notes varies among note takers, the C-Print printout is as near the original message as possible and preserves its meaning. The results from this study suggest that students rated C-Print about as favorably as students had rated the steno system in the previous study. C-Print, however, is generally the more cost-effective of the two systems. Due to the shorter training time of C-Print, approximately 6 weeks, many persons can be trained and placed in classrooms as support professionals at a reasonable cost. Equipment costs are also low.

Educational programs are frequently interested in using C-Print as the only support service because this approach is less costly than including it as an additional service along with others. Student responses indicated that use of C-Print as the only service would probably be acceptable to some students, but that it would not be to others.

Results pertaining to individual differences in questionnaire responses were consistent with the interview data. These results indicated that not all students reacted more favorably to C-Print than to interpreting or note taking. This pattern of relationships between communication background and preferences and response to C-Print was consistent with the previous research with a steno system (Stinson et al., 1988). For both the previous study and this study, students who were relatively proficient in reading and writing English, and in speechreading, responded more favorably to the speech-to-text system. The generally favorable response to C-Print came from a population of deaf and hard-of-hearing students with unusually high reading proficiency; less proficient readers may prefer an interpreter. A study under way with high school students, who are less proficient readers than those in this study, is addressing this question.

One limitation of this study is that C-Print was used only in certain types of classes, primarily lecture-oriented courses in business or liberal arts. For certain instructional situations, such as laboratories, the system may be inappropriate (Haydu & Patterson, 1990). In addition, a little more than half of the students served by C-Print completed questionnaires or interviews. It is possible that students who participated in the study had more favorable attitudes about the system than those who did not participate. Also, the questionnaire sample was small.

Research to develop a more comprehensive understanding of the benefits and limitations of educational technologies, such as C-Print, must use a variety of methodologies and must evaluate the technology with various groups and in different settings. This study used quantitative and qualitative methodologies. Other studies are needed to obtain additional objective data. These include investigation of the effect of C-Print on memory for lectures and of the system's influence on educational achievement. Such studies are currently under way.

This study contributes to the accumulating evidence that indicates that a speech-to-text transcription system, such as C-Print, is an effective way of increasing accessibility to information in the mainstream classroom for deaf and hard-of-hearing students. Evidence also supports the perspective that it is desirable to match support services to the needs and preferences of individual students, given considerations of cost and availability. In making recommendations regarding support services to deaf or hard-of-hearing students, support service professionals can use information such as the finding that proficiency in English appears to be a good predictor of the perceived benefit obtained from C-Print. This does not imply that a student's predicament and preference should not be taken into account. However, it does imply that a student's preference is not the only factor that should be considered in selecting an appropriate support service.

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Appendix 1

Questionnaire Items Used in the Study

Items	Response Options
Which do you use more?	Circle answer: (a) Notes from note taker; (b) C-Print notes
How do you use the C-Print notes to study?	Can circle more than one response: (a) Skim the notes and highlight important information; (b) Make an outline from the information; (c) Note unfamiliar vocabulary and ideas; (d) Other? (write in)
How much do the C-Print notes help you with this course?	Circle one: (a) C-Print notes do *not* help at all; (b) C-Print notes help me a little; (c) C-Print notes help me enough; (d) C-Print notes help me very much
Often the C-Print operator has to summarize information. Is that acceptable to you? Do you feel you are getting the important points?	(Open-ended question; responses coded)
How much of the lecture can you understand from watching the interpreter?	Circle answer: (a) 100%, (b) 90%, (c) 80%, (d) 70%, (e) 60%, (f) 50%, (g) 40%, (h) 30%, (i) 20%, (j) 10%, (k) 0%
How much of the lecture can you understand from watching the C-Print display (TV or laptop)?	Circle answer: (a) 100%, (b) 90%, (c) 80%, (d) 70%, (e) 60%, (f) 50%, (g) 40%, (h) 30%, (i) 20%, (j) 10%, (k) 0%
If there is an interpreter, but no note taker is available, how helpful would the C-Print system be?	Circle answer: (a) C-Print does *not* help at all; (b) C-Print helps a little; (c) C-Print helps enough; (d) C-Print helps very much
If *no* interpreter and *no* note taker are available, how helpful would the C-Print system be?	Circle answer: (a) C-Print does *not* help at all; (b) C-Print helps a little; (c) C-Print helps enough; (d) C-Print helps very much

Appendix 2

Interview Questions

I. Real-time Display

1) How much of the lecture can you understand watching the display?
2) Do you have any problems with the display itself or with watching the display?
3) When watching the display, do you know when the teacher is asking a question and wants an answer?

II. Text "Condensing"

1) The captionist has to "condense" (summarize) information often in class. Is that acceptable to you? Do you feel you're getting the important points?
2) Do you think any information has been missing from the display?

III. C-Print Notes

1) What are the advantages and disadvantages of the C-Print notes?
2) Please tell us what you do with the C-Print notes from the time you get them to the time you are finished with them.

3) How do you use the C-Print notes to study (e.g., skim the notes and highlight important information; make an outline from the information; note unfamiliar vocabulary and ideas; other ways)?

IV. Adequacy of the C-Print System

1) If there was an interpreter, but no note taker was available, how adequate would the C-Print system be?
2) If there was a note taker, but no interpreter was available, how adequate would the C-Print system be?
3) If no interpreter or note taker was available, how adequate would the C-Print system be?

V. General Questions

1) For you, what is the best thing about C-Print?

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Inclusive Instruction and Learning for Deaf Students in Postsecondary Education

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This article explores how students who are deaf and their instructors experience mainstream college classes. Both quantitative and qualitative procedures were used to examine student access to information and their sense of belonging and engagement in learning. Instructors were asked to discuss their approach to teaching and any instructional modifications made to address the needs of deaf learners. Results indicate that deaf students viewed classroom communication and engagement in a similar manner as their hearing peers. Deaf students were more concerned about the pace of instruction and did not feel as much a part of the "university family" as did their hearing peers. Faculty generally indicated that they made few if any modifications for deaf students and saw support service faculty as responsible for the success or failure of these students. We discuss results of these and additional findings with regard to barriers to equal access and strategies for overcoming these barriers.

Deaf students are attending mainstream postsecondary educational programs in ever increasing numbers. Currently, 20,000 deaf and hard-of-hearing students are mainstreamed in approximately 2,360 postsecondary programs (Lewes, Farris, & Greene, 1994). We have come a long way in terms of providing support services such as interpreters, notetakers, and tutors. Yet we have not systematically documented what works and does not work regarding full inclusion of this population. There is always the danger that instructors and students will perceive the presence of support services in their classes as "full accommodation." In fact, this is only the first step. In this article, barriers to inclusive education for deaf postsecondary students, as well as strategies for overcoming barriers, are explored. Findings are presented from an ongoing program of applied research at a large postsecondary program that focuses on inclusive education for deaf students enrolled in mainstream classes.

The article is organized into four sections. In the first section, background information is provided regarding legislation that has had an impact on mainstreaming students with disabilities at the postsecondary level, as well as selected literature on the topic of inclusive education. The second section describes the design of the research, including subjects and methodology. The third section presents research results. The article concludes with a discussion of the implications of this research for inclusive education of deaf students at the postsecondary level.

Background

During the two decades following passage of the Individuals with Disabilities Education Act (IDEA), educational program reform at the local and state levels increased dramatically. The primary goal of the legislation and subsequent reform was to ensure that all students shared equal educational opportunities and access to the same "general" curriculum. According to the U.S. Department of Education (1997), three times the number of young people with disabilities are now

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enrolled in colleges or universities. However, the Department of Education also acknowledges that many children with disabilities remain excluded from the general curriculum.

From discussions of inclusive education (e.g., Chalmers & Olson, 1995), its characteristics (e.g., Dalheim, 1994), and strategies for implementation (e.g., Falvey, 1995), four themes emerge: (1) an inclusive environment can be conducive to learning for all students, (2) some teaching styles are more consistently connected with an inclusive environment, (3) the personal learning styles of students need to be considered in programmatic design, and (4) mere physical proximity is insufficient to achieve the goal of inclusion. Unfortunately, outcome-based evaluations of the efficacy of inclusive education in achieving its goal—equal opportunity and access to the general curriculum—continue to lag behind program reform.

As a member college of the Rochester Institute of Technology (RIT), the National Technical Institute for the Deaf (NTID) is in a unique position to identify the efficacy of inclusive education in achieving the goal of equal opportunity and access to the general curriculum. More than 400 deaf students who are fully matriculated in the other six colleges of RIT receive support services through NTID. Thus, RIT/NTID has a wealth of experience and expertise in providing tutoring, notetaking, and interpreting for students who are deaf.

Several outcome-based studies of inclusive education conducted at NTID support the observation that mere physical proximity often promotes only the illusion of integration and that additional accommodations may be necessary to overcome less obvious barriers (Foster & Brown, 1989; Foster & Walter, 1992; Saur, Popp-Stone, & Hurley-Lawrence, 1987). In a reflective essay written from the perspectives of a hearing instructor and a deaf student, Foster and Holcomb (1990) explored the importance of grapevine information and student rapport in university settings, noting that both are difficult for deaf students to access. Other research at NTID has focused more specifically on the cognitive and affective dimensions of classroom communication and engagement. In this vein, it was found that as students feel at ease with their communication with teachers and peers, they see themselves as having control in the educational setting and are more likely to become engaged, active learners (Braeges, Stinson, & Long, 1993; Garrison, Long, & Stinson, 1993; Long, Stinson, & Braeges, 1991; Stinson, Liu, Saur, & Long, 1996). These and other studies suggest that, even with a comprehensive program of classroom support services, access to classroom communication is a unique challenge for deaf students. Here are examples:

1. Deaf students using an interpreter experience a "lag time" in receiving information. The interpreter will finish signing what has been said about 5–10 seconds after the speaker stops speaking, which can exclude deaf students from participating, since by the time the student has received the full message the instructor has already identified and called on someone else.

2. Deaf students may rely on speechreading for information. Yet instructors often break visual contact between the student and their speech while writing on the board, reading from papers held too close to their faces, or pacing back and forth.

3. In labs or computer courses, instructors may speak while manipulating physical objects or performing tasks on a projected screen. Deaf students must choose whether to watch the interpreter or the instructor/screen, losing half the information.

4. Deaf students are rarely included in informal exchanges among hearing students regarding instructor expectations, study tips, and unspoken rules for class behavior and organization, thus missing important but "unpublished" information.

These examples demonstrate that there is more to inclusive instruction than physical proximity and the provision of support services. Informal conversations, instructor styles and behaviors, student interactions, and the nature of the information being conveyed subtly but significantly shape the teaching and learning experience. In this article the focus is on these less obvious but equally important components of educational access.

The purpose of this study is to describe conditions that affect access to teaching and participation in learning by deaf postsecondary students in mainstream class settings. Critical areas explored include the perceptions of deaf and hearing students regarding communication and engagement within the class and the perceptions of instructors regarding their teaching experiences with deaf students. We hope that this research will lead to the identification of strategies and conditions that enhance full academic access and accommodation of mainstream deaf college students.

Method

During the 1996/1997 academic year, instructors and support faculty working with deaf RIT students majoring in business, computer science, or information technology were invited to participate in a collaborative study of academic mainstreaming. Quantitative and qualitative research methods were used to collect data from students, instructors, and support faculty regarding academic inclusion. Quantitative tools include the Academic Engagement Form (AEF) and the Classroom Communication Ease Scale (CCES). Interviews were conducted with instructors using qualitative methods.

Academic Engagement Form. Engagement refers to the extent that students' efforts, persistence, and emotional states during learning activities reflect a commitment to learning and successful academic performance (Skinner, Wellborn, & Connell, 1990). Engaged students show persistence and interest in academic tasks and tend to achieve academic success. In this study, students were asked to respond to 114 items designed to assess affective and behavioral aspects of engagement. Items look at aspects of active learning, perceptions of teachers, strength of association with other students in class, and feelings of belonging at RIT. These items were adopted from the Rochester Assessment Package for Schools (RAPS), an instrument designed to assess a number of motivational dimensions with hearing students (Skinner et al., 1990). Additionally, students were asked four open ended questions covering class participation and belonging.

Communication Ease Scale. One way of assessing how successfully an inclusive environment promotes equal access to instruction is to compare the perceptions of deaf and hearing students about their ease or difficulty in communicating. For this study, a modified version of the CCES was used, in which communication ease is conceptualized as having two dimensions: a cognitive dimension and an affective one. The CCES (Garrison, Long, & Stinson, 1993), uses a six-alternative Likert scale to examine each dimension. The cognitive dimension is concerned with self-perceptions about the amount and quality of information that students receive and send. The affective dimension asks students to rate how they feel when communicating with hearing and deaf peers, teachers, and support staff. Both positive (feeling good, relaxed, comfortable, confident) and negative (frustrated, nervous, upset) affective responses are explored, and students responded to a total of 110 items. Additionally, students were asked two open-ended questions regarding their best and worst classroom communication experiences.

Deaf and hearing business ($n = 24$), computer science ($n = 4$), and information technology ($n = 48$) majors were paid $10 each to fill out the AEF and CCES. Hearing students were matched by gender, course, and major with the deaf students. Materials were placed in student departmental mail folders and students were informed about the study and reminded via electronic mail to return the questionnaires. Seventy-six students (46 deaf and 30 hearing) responded to the questionnaires. The average student was 23 years old; 26 were female and 50 were male.

Instructor interviews. Interviews are a conventional qualitative research technique used to explore in detail with research participants their experiences, beliefs, and perspectives regarding a particular idea, practice, circumstance, or event (Spradley, 1979). By asking individuals general questions and encouraging them to elaborate on their ideas through personal stories and examples, data are collected that can then be analyzed for code categories, that is, groupings of types of responses similar in nature. This approach often yields information inaccessible through traditional quantitative collection strategies.

A target number of 15–20 instructor interviews was established by the project team as sufficient to describe the range of experiences and perspectives of this group. A list of 31 potential instructors to be contacted for interviews was then developed by NTID faculty who provide tutoring for students enrolled in supported courses. In developing instructor lists, consideration was given to the diversity of the group. Instructors new to RIT were included as well as those who had worked at RIT for many years. Instructors were selected who had different teaching styles and course structures (e.g., lecture versus discussion). Male and female instructors were included in each of the programs offered through Computer Science, Information Technology, and Business (including Management, Finance, Information Systems, and Marketing). This list was then organized so that, by working from the top of the list down, within programs, we would get the most diverse group possible.

Instructors were contacted via e-mail or telephone by one of the three researchers conducting the interviews. The project was explained, and instructors were invited to participate in an informal, semi-structured interview. The 17 interviews completed represent those who agreed to participate; approximately two-thirds were from the top half of names listed within their program. Interviews were conducted with instructors teaching courses in Computer Science (4 of 6), Information Technology (5/9), Management (1/3), Finance (3/6), Information Systems (2/3), and Marketing (1/2). The range of years teaching at RIT for the interview group was from 2 to 23 years, with an average of 12 years. Of the 17, 11 are male (from a total of 20 on the list) and 6 are female (from a total of 10).

Interviews lasted approximately 1 hour. Core topics covered in the interviews include instructors' perceptions of (1) deaf students enrolled in their classes, (2) barriers to access within their classes, and (3) strategies they use to facilitate access to their course materials. With the instructor's permission, interviews were recorded on audiotape.

Results

Quantitative Results

The first set of analyses focused on comparing the deaf and hearing responses to the Academic Engagement Form and its four open-ended questions. Deaf and hearing respondents were then compared on the Classroom Communication Ease Scale and its two open-ended questions.

The AEF was found to be highly reliable for both hearing (Cronbach's α = .96) and deaf respondents (α = .92). Deaf students reported being just as actively engaged in learning (mean = 4.08) as hearing (mean = 4.18) students when responses to the entire scale were analyzed. Responses to subscales indicated that hearing students felt more like they belonged at RIT and were more a part of the RIT family than did deaf students. Items such as ("I feel like I belong at RIT," "The people at RIT are like a family," and "I'm proud to be an RIT student") were somewhat more frequently endorsed by hearing students than by deaf students, $t(73) = 1.88$, $p = .06$.

Hearing and deaf students also differed on their perception of the appropriateness of the teachers' pace when presenting information. Deaf students less frequently, $t(74) = 4.21$, $p < .01$, perceived the teachers' pace (e.g., "My teacher makes sure I understand before he/she goes on," "My teacher makes sure that he/she doesn't teach faster than I can learn") as optimal for learning than did hearing students.

As part of the AEF, students were asked to supply their own words to the following incomplete sentence: "I feel like I am part of the classroom when I ______." Both groups reported that participation was the most frequent reason for feeling a part of the class. This sentiment was expressed by 66% of the hearing and 44% of the deaf students. Their comments are best captured by a deaf student who said, "participate and learn by doing" and a hearing student who said, "am encouraged to participate and allowed to figure things out for myself." Thirty percent of hearing students and 33% of the deaf students mentioned that they feel part of the class when they understand the material. Based on the comments of both groups, understanding the material allowed them greater participation, which was the key element to feeling part of the class.

What do students do when they have difficulty learning? Students responded to this statement: "When I get stuck, I ______." in their own words. Twenty-two percent of hearing students and 24% of deaf students said they use friends or classmates to help them when they get stuck. More deaf students (31%) mentioned going to the teacher for help than did hearing students (22%). Deaf and hearing students differed with regard to their use of tutors and trying to "figure it out myself." Deaf students were less likely (15%) to try and resolve it themselves and were more likely to look to tutors for support (29%) than were hearing students (30% and 4%, respectively). This finding may be influenced by the support system available to deaf students at RIT. Deaf students in the majors under study have full-time faculty tutors available to provide assistance, whereas this support is not provided for hearing students. The availability of tutors and notetakers may also contribute to deaf students being less likely than their hearing peers to try and resolve learning problems independently.

Cronbach's alpha analyses indicated that agreement on the CCES was also highly reliable for hearing (α = .95) and deaf (α = .94) respondents. When overall ease of communication was examined, we were surprised to find no statistically significant differences between responses for the two groups, given the potential for communication difficulties when language interpretation occurs. That is, the deaf students (mean = 3.95) perceived the ease of communication with teachers and peers similar to their hearing peers (mean = 4.01). Deaf students' feelings about communication, both negative (nervous, frustrated, upset) and positive (relaxed, comfortable), were also very similar to their hearing peers'. This finding is important given the complexity and barriers to communication that exist for deaf students in mainstream settings. The success of interpreters and notetakers in providing equal access to communication for deaf learners in mainstream classes is highlighted by this finding.

Students were asked to respond to two open-ended sentences about communication using their own words. "Communication in the classroom is best for me when ________" and "Communication in the classroom is worst for me when ________." Deaf students' responses tended to focus on the role of the interpreter as a mediator of the quality of the communication. Sixty percent of the deaf students mentioned the interpreter when discussing the best communication. The student who said that the "interpreter is being effective with signing skills and understand the concepts in class" is representative of most responses. The complexity of being "effective with signing skill" is clear, insofar as some students refer specifically to the importance of ASL skills while other students mention how important it is for him or her to read lips or have an oral interpreter.

Hearing students' comments about the best classroom communication focused on the teacher being clear, easy to understand, and organized; the pace was not too fast; and the teacher involved students. One hearing student summarized the optimal communication environment as one in which "the classes are small to medium sized, [and] the teacher is interested in listening to the students (usually younger teachers)." Two hearing students indicated that having an interpreter in the classroom helped their comprehension because when "deaf students and an interpreter are present . . . the teacher moves slower in presenting the material which allows me to understand more." Both groups indicated that the instructor's pace influenced ease of classroom communication.

The interpreter was mentioned by 48% of the deaf students in their discussions of when communication in the classroom is worst for them. Not having an interpreter, or not being able to see the interpreter, was mentioned by a number of students: "There is no interpreter and I feel frustrated about participation." When the interpreter is present, the student may need a specific skill level and sign system that is not being accommodated: "The interpreters try to sign ASL and don't understand the content then sign most in English" or "The interpreter does not understand what I am saying, making me to repeat and forget what I wanted to say." Others pointed to the importance of the interpreter understanding the class material: "Interpreter couldn't perform his/her duty if he/she cannot understand the concepts of class." Thus, the central role of the communication facilitator is reflected in both the positive and negative communication experiences of deaf postsecondary learners.

Hearing students' difficulties with classroom communication focused on the pace of the teacher, distractions from other students, and teachers using "straight lecturing" as the primary form of information delivery. Again, the positive influence of deaf students in slowing down instruction was noted. One hearing student commented on how things are difficult for him when deaf students are not in class. As he put it, "[when] there are not deaf students and the teacher is presenting material too quickly for me to understand, forcing me to exclude myself from class discussions and questions."

Qualitative Results

The quantitative data described before focuses on student perceptions of the teaching and learning experience. However, this is only one piece of the puzzle. Another important piece involves instructors' perceptions of what it is like to work with deaf students. How do instructors feel about teaching deaf students? Do they see differences in the performance or behavior of deaf students? What do they feel are the major barriers to access and participation for deaf students in their classes? Do they do anything differently or special to accommodate the needs of deaf learners? These and other questions were raised through qualitative interviews with 17 instructors who have had deaf students in their classes. Semi-structured interviews were used because this approach is more likely to yield the level of detail and "real-life examples" that we felt were crucial to understanding instructors' perspectives. Tape-recorded interviews were transcribed verbatim and the transcripts coded for recurring patterns and themes (Bogdan & Biklen, 1992). In this section, major topics are reviewed, drawing on the interviews for illustrations.

Who is responsible for access and accommodation? Instructors' comments suggest that there is diversity of opinion regarding the answer to this question. Their responses range from the perspective that the student and NTID are responsible for access and learning, to a perspective in which teachers see themselves as having primary responsibility for the success of deaf students. At a midpoint on this continuum is the notion of shared responsibility, in which instructors, students, support personnel (NTID), and college personnel (mainstream college) share responsibility for ensuring that instruction and learning are accessible for deaf students. Most comments fall somewhere between shared responsibility and the belief that NTID and the deaf students are primarily responsible. The degree to which instructors are willing to modify their classes, instructional materials, and evaluation procedures is an outgrowth of their perspectives about responsibility. The continuum in Figure 1 summarizes the range of both responsibility and instructor-generated modifications.

Comments that suggest that instructors have little or no responsibility to facilitate the inclusion of deaf students within their class and that learning is solely the responsibility of the student, hearing or deaf, with or without support services, were often framed in terms of "doing nothing different," and "it is the student's responsibility to learn." Instructional styles are not modified, nor is special attention given to deaf students or to hearing students who may have specific learning preferences or needs. The basic approach of these teachers is that they do not believe their instruction needs to be modified to fit the needs of any student. Deaf students are simply an extension of this approach, amplified by the level of resources provided by NTID and the large number of deaf students on the RIT campus. Implicit in this perspective is the notion that NTID has "leveled the playing field" by providing interpreters, notetakers, and tutors, and that instructors therefore can, and in fact should, proceed as usual. As one instructor put it, having deaf students in class is "transparent"; he further explains that this is a computing term meaning "that you are unaware that there is anything different." If support services are not provided or fail to accommodate the teacher's preferred approach, the responsibility for change rests with the support team and NTID. The following example illustrates this viewpoint:

> Instructor: The only issues that ever arise tend to be technical, like scheduling an interpreter . . . I run . . . 2-hour classes . . . and I don't take a break. And I am not going to take a break, and this can create difficulties with interpreters. And I have told the support team, "Look, if interpreters can only work for an hour for very logical and defensible reasons, I have no problem with that. Just send another one in at the end of one hour. . . ." And you know, they have to explain to me, "Well, the way we schedule them they need time to get from A to B." And so sometimes there has been a break in

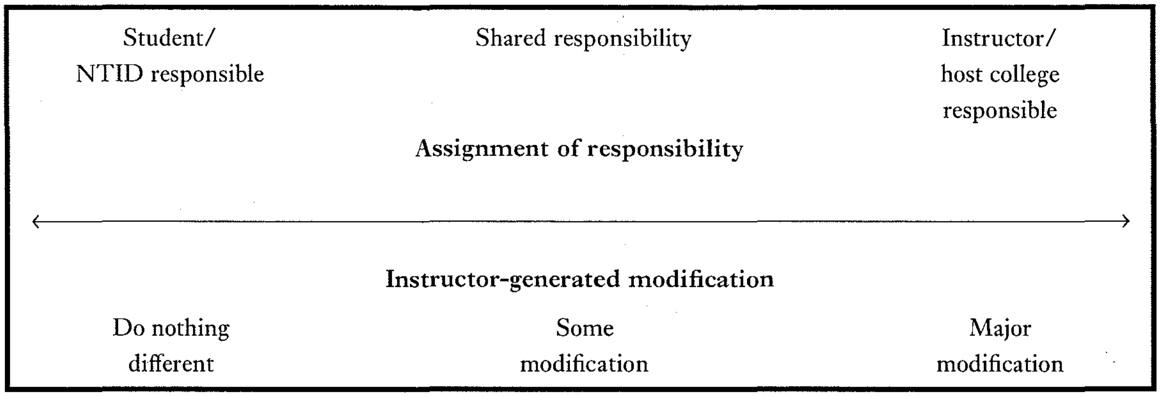

Figure 1 Continuum illustrating range of instructor comments regarding assignment of responsibility for accommodation of deaf students and instructor-generated modifications.

> there where there is no interpreter. But it hasn't happened recently.
>
> Interviewer: How do you handle that if that happens?
>
> Instructor: I just teach. The same way I always teach.[1]

At the other extreme is the perspective that instructors play a central role in the success of all students in their classes, including deaf students. In this vein, one instructor said that he always reviews the notetaker notes in conjunction with test development or evaluation of grades in order to ensure that material covered on tests is available in the notes. He also makes allowances for the difficulties deaf students sometimes have expressing their thoughts in written English: "I don't grade hearing-impaired students the same as I grade hearing students. . . . I don't expect good grammar [from hearing impaired students]. I really look to see if it says one thing, to see if there is any way it could actually mean another, correct, thing. I won't do that with a hearing student."

Somewhere between these two extremes is the opinion that responsibility for accommodation of deaf students in mainstream classes is shared. One person described this in a holistic fashion: "It is an instructional system. . . . [Y]ou have got the professor, you have got the interpreter, you have got the notetaker, and you have a tutor . . . so, what I do is view us as a team."

Most instructors make at least a few accommodations for deaf students. Common examples include introducing the interpreter, making sure that there is a notetaker in class, and giving interpreters a break every hour. Others attempt to modify their instructional style or pace, or eliminate activities such as term papers, which they feel place deaf students at a disadvantage. However, even those who fall somewhere near the midpoint of this continuum tend to define NTID as having primary responsibility for deaf students.

Comparisons of deaf and hearing students' academic performance. A major concern raised by many instructors is that deaf students do not perform as well academically as hearing peers. Perceived reasons given include (1) lack of preparation, (2) lack of motivation, (3) overreliance or dependence on support systems, (4) inability of deaf students to get full information (interpreter difficulties, poor notetakers, indirect nature of support services for communication and learning), (5) poor English skills, and (6) the belief that mainstreaming is the result of "political correctness" rather than of sound academic practice. These perspectives are further reflected in instructors' suggestions for further research, which include a more systematic comparison between the grades of deaf and hearing students, the number of times they withdraw from a course or repeat it, and the relative success of deaf students taught by NTID support faculty as compared with those who receive instruction through interpreters.

Learning about deaf students and how to accommodate special learning needs. Instructors' experiences learning about deaf students and possible accommodations span the gamut from one person with many years of classroom experience teaching deaf students prior to coming to RIT, to another who had no experience at all and was not even informed that he would be teaching deaf students. As he put it, "The first day I was here, I walked into a class with deaf students and an interpreter. I had never worked with one before, no one told me this was going to happen. . . . [F]or five minutes, [I thought] this is the strangest thing in the world! How am I going to do this? And, you know, then I watched the interpreter do her thing and it seemed OK and that was the end of it. . . . I said, 'Who are you?' She was standing up on the stage right next to me and I said, 'What are you doing here?' "

Most instructors, however, were neither as experienced nor as taken by surprise. They learned about deaf students from a variety of sources, often in a serendipitous fashion. Interpreters were often cited as important sources of information, likely because they are in the class with the students and instructors. Often, instructors said they ask interpreters for feedback on their teaching and invite them to tell them when they are speaking too quickly or need a concept repeated. Others said they go to support faculty when they need information. Trial and error is yet another learning strategy, as are informal conversations with departmental colleagues. Physical proximity often dictates who will be tapped for assistance and ideas. In one case, support faculty are housed in the same building as the instructors and often are queried when passed in the hall. Another department is adjacent to the interpreter support group, facilitating questions and communication support on an informal and "on the spot" basis.

Training and professional development Instructors were asked whether they would be interested in training and professional development regarding accommodation of deaf students within their classes. While many said they would be interested in having more information or ideas, most were not enthusiastic about investing much time or energy in these kinds of activities. For many, time was the biggest barrier to participation, particularly in combination with the perceived lack of benefit of this training. This low "cost-benefit" factor made many reluctant to participate in training efforts. Generally, their explanations for low interest levels were tied to the earlier assignment of responsibility to NTID for accommodation, or to the perception that participation would yield few benefits. Several instructors noted that deaf students are just a small percentage of their classes. Also, they may have deaf students only one out of three quarters or not at all. They find it difficult to justify taking time to improve instructional strategies for such a small group, particularly when their annual appraisals and increments are often tied to student evaluations (dominated by hearing students). As one person said:

> I don't think there would be a lot of incentive on my part at this point [to attend workshops about teaching deaf students] because the number of students is so small. I am worrying about the course evaluation scores of the 95% of the other students and some of the things that I do for the other students to improve the course for them will carry over to the hearing-impaired anyway. But to think up special strategies for that 5% of . . . hearing impaired that would just affect them, it is not worth it.

As this instructor cited notes, the most attractive instructional strategies benefit both deaf and hearing students. For most instructors in mainstream classes, deaf students are simply not even a minor consideration. One instructor made the following observation regarding the potential interest in the department for a workshop on teaching deaf students:

> [Having deaf students in class] is a nominal part [of what we do]. It is immaterial. They [colleagues] have only a couple [of deaf students]. They have an interpreter. They have notetakers. And they would get by in their office writing if there is not an interpreter present. And you know, in the meantime their focus is really on very different things. . . . [I]t would be very difficult in the context of the competition for their time and energy for them to view that [workshop] as very important. And I am not saying that because they view deafness as an unimportant social or professional issue. It is just that

there are not enough deaf students to justify that type of effort.

Central to this person's comments is the idea that instructors are busy and have many demands on their time. Research, publishing, curriculum development, and satisfying the instructional needs of the majority of their students take a priority in their schedules. Any efforts to provide information specifically focusing on deaf students must take this perspective into consideration.

Beyond the obvious: barriers to access for deaf students in mainstream college classes. In describing their instructional experiences, instructors were asked to discuss elements of successful instruction with all students and then to compare the impact of these practices on the deaf students in their classes. Analysis of their comments reveals several subtle barriers to access for deaf students in mainstream instructional settings.

The physical set-up of many classrooms creates barriers for deaf students by reducing the degree of direct contact between student and instructor. For example, when instructors were asked how they know whether students in their classes are "getting it," they generally spoke about watching the students for visual cues, including eye contact and body language. They readily admitted that this is less possible with deaf students, who often sit to the side of the room and focus on the interpreter. In a similar vein, an instructor said that he often steps down from the elevated stage and walks along the aisles when lecturing; however, he almost always walks along the aisle furthest from the deaf students, since he does not want to walk between these students and the interpreter.

Some teaching strategies and instructional styles make classroom learning more difficult for deaf students, even with interpreters and notetakers. For example, when instructors are writing a computation on the board and talking at the same time, students must choose whether to capture the comments by watching the interpreter or follow the computation by watching the board. Similarly, in many computer courses instructors project a computer screen and perform manipulations on this screen while describing or explaining their actions; again, deaf students must choose which half of the message they want to receive. While several instructors acknowledged that this is a problem, none was able to offer concrete ideas for improving access to this type of instruction.

Participation of deaf students is sometimes limited by differences in the ways that instructors respond to potentially disruptive behaviors in the class. The most frequently discussed example involves students' talking during lectures. Hearing students talk orally, or "with voice," while deaf students sign among themselves. Instructors said they ask hearing students to stop talking during lectures but often ignore the signed conversations of deaf students. When asked to explain this decision, they said that they speak to the hearing students because they find the spoken conversation personally distracting, or they feel it is distracting for other hearing students. Signed conversations, on the other hand, are not disruptive to the hearing students or to the instructor and are thus more often tolerated. Instructors sometimes added that they are reluctant to interrupt deaf students because they are unsure of what they are discussing. For example, they wonder if students are talking about the class material, which seems a legitimate reason for them to be talking. When asked if they would tolerate conversations about coursework among hearing students during class, they said that they would ask these students to share their question with the class so everyone could benefit but added that this is only possible because they could discern the nature of the conversation before deciding whether to intervene. By not asking the deaf students to share their conversations, they are indirectly limiting the participation of these students and perhaps contributing to the perception of deaf students that they do not "belong" at RIT as much as hearing students.

Discussion

Two themes emerge as important across both quantitative and qualitative findings. First, the perceptions of deaf students with regard to educational environments are generally not significantly different from those of hearing students. Both express similar levels of classroom engagement and communication ease. Both define participation and understanding of course material as central to their feeling a part of the class. Both indicate that instructors' pace influences their ease of communication in class settings. Their differences are more related to the specific vehicles through which they interact within their classes. For example, while overall communication ease is similar for both groups, deaf students emphasize the role of the interpreter in effective communication of information, while hearing students focus on the role of instructors. Similarly, while both agree that participation is important for feeling a part of the class, deaf students express this sentiment less frequently than hearing students, a result probably influenced by the constraints imposed by indirect communications with instructors and hearing students.

Second, the continuum of responsibility for classroom learning on which faculty vary affects both deaf and hearing students. At the one end are teachers who assume it is their responsibility to share information in a way that helps all students learn, regardless of hearing status. These teachers do not assume that there is something wrong with students who do not understand information. Instead, they assume there is something wrong with the interface between the teacher and the student, or perhaps with their own presentation. These teachers do not differentiate between their responsibility for hearing and deaf students. They want all their students to "get it." At the other end of the continuum are teachers who assume that it is nearly all the students' responsibility to understand information as it is given to them. These teachers do not differentiate between their treatment of deaf and hearing students as much as they emphasize that all students must learn for themselves and that the teacher is not responsible if someone does not "get it." These teachers do not focus on the teacher/student interface; they do not conceptualize an interface. While the special needs of deaf students push both ends of the continuum to extremes, there are nonetheless points along the same continuum that apply to all students and instructors.

Further study of this continuum and the kinds of interactions it represents between teachers and students yields implications for practice. For example, some hearing students commented that the slower pace of instruction used when deaf students are present is beneficial to them. Several instructors indicated that, while they tend not to make adaptations specifically for deaf students, they would do things to improve their overall teaching effectiveness if it enhanced their student ratings. It is therefore important to identify teaching practices that both meet deaf students' needs and are beneficial to all students.

The continuum also holds implications for student roles and responsibilities. While it is beyond the scope of this study, we have observed students (both deaf and hearing) who remain completely passive even when the instructors' pace is too fast to be understood or when course materials are confusing. We recommend further research that explores more fully the behaviors of students along this continuum, as well as strategies that students can employ to increase their access to learning.

What specific recommendations for practice emerge from this study? First, emphasis should be given to the similarities between deaf and hearing students and those instructional practices that enhance learning for everyone.

Second, instructors should be selected for interventions who are interested and willing to modify their teaching strategies to facilitate inclusion of all students. Furthermore, they should have sufficient and continuous exposure to deaf students in their classes. These instructors can then encourage and model good practices for their colleagues.

Third, intervention strategies should be practical and reasonably easy to implement. For example, it is not helpful to suggest that instructors "be more sensitive to deaf learners." More practical suggestions might include (1) seating interpreters near the lectern in order to decrease the visual distance between the instructor and the interpreter, (2) providing handouts of notes that will be displayed on the board during class, or (3) pausing and counting to five after asking a question to facilitate inclusion of deaf students, as well as hearing students who may need an additional few seconds to process information.

Fourth, strategies should be disseminated through user-friendly vehicles. For example, a web page that can be accessed at any time with a list of options (strategies, personal stories of frustrations and successes, and a chat room) may be preferable to traditional workshops that often disrupt busy schedules and require travel to central locations on campus.

Fifth, excellence in teaching should be rewarded. The power of professional recognition, merit increments, and positive appraisals cannot be underestimated in changing the behaviors of instructors.

In conclusion, mainstream postsecondary educational settings pose special challenges for deaf students. Interventions must be designed that are specific, involve changes in the behaviors of both students and instructors, and target and reward best practices and educational models. Additionally, the extended benefits of improved access to instruction for deaf students to all students must be emphasized. Efforts to focus attention only on deaf students is almost certain to meet with defeat due to the relatively small numbers of these students and the overall reluctance of college faculty to modify their practices for a single target group.

Note

1. The use of the notation " . . . " indicates that text from the interview is omitted. This is a space saving convention, generally used when there is repetition or extraneous material in the comment. A word or phrase inserted into the text by the researcher is set off with brackets. This is generally used for clarification.

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COMPUTER-ASSISTED REMOTE TRANSCRIPTION (CART): A TOOL TO AID PEOPLE WHO ARE DEAF OR HARD OF HEARING IN THE WORKPLACE

New technologies are needed that will allow people who are deaf or hard of hearing to participate fully in meetings held in

the workplace. Computer Assisted Remote Transcription (CART) is a procedure in which a stenographer transcribes a meeting from a remote location. This study investigated the feasibility of the CART system through an experiment and a case study. An experiment was conducted to learn whether a stenographer could transcribe a meeting of up to 10 speakers accurately from a remote location. In the case study, the CART system's usefulness and practicality were investigated in the workplace for a professional with a hearing impairment. The results indicated that, after a short familiarization period, a stenographer should be able to transcribe a meeting of up to 10 speakers with fairly good accuracy, but the results also revealed several problems with the practicality of the CART system in the workplace.

Evaluation of on-the-job performance and problems of people who are deaf or hard of hearing has consistently shown that one of their major difficulties is participation in meetings (Crammatte, 1968; Foster, 1992; Mowry & Anderson, 1993). Reported accommodations during meetings include the use of lipreading, notetakers, and American Sign Language (ASL) interpreters (Crammatte, 1968; Foster, 1992; Mowry & Anderson, 1993). Lipreading is often ineffective because it depends on the size of the meeting, the lighting and seating arrangements, and the ability and willingness of the hearing speakers to make lipreading available and to repeat information on request (Crammatte, 1968; Foster, 1992). Using a coworker as a note taker is also an inadequate accommodation. Notetaking is slow, and it causes a time lag (Crammatte, 1968). Some people who are deaf or hard of hearing receive written summaries of meetings after they are over (Foster, 1992); clearly, this is an inadequate solution. The use of an ASL interpreter is an effective accommodation for many people who are deaf or hard of heating; however, many adults who were deafened postlingually, or who were educated in oral environments do not have a good understanding of ASL and prefer English as their primary means of communication. In addition, ASL interpreters may be difficult to locate and to schedule, and more than one interpreter must be hired for longer meetings, driving up the cost. Clearly, there is a need for new options that will enable people who are deaf or hard of hearing to participate fully in meetings.

Many deaf students have used the Real Time Graphic Display of Speech (RTGD) successfully in the classroom (Stuckless, 1983; Stinson, Stuckless, Henderson, & Miller, 1988). In this system a professional stenographic captioner (stenographer) provides simultaneous, word-for-word transcription of a speaker's words. The stenographer types the speaker's words as phonetic symbols on a stenotype machine. The sterotype is connected to a computer that translates the phonetic shorthand into English. This translation is achieved through the use of standard real-time captioning software, which stenographers can customize using a personal dictionary that recognizes their own shorthand techniques and the technical terms and proper names that are appropriate to the course material (Stuckless, 1983). The text is then displayed on a standard TV monitor that can be viewed by any student in the classroom.

Stuckless (1983) described the accuracy of the RTGD system in use at the Rochester Institute of Technology (RIT) for deaf students at the National Technical Institute for the Deaf. In this investigation, all transcriptions were performed by a single stenographer who was certified at 225 words per minute. The accuracy of the transcription was investigated for the stenographer in 10 different courses during one year. After two weeks of use in a course, the accuracy was found to be 85% correct. Transcription accuracy improved to 90% correct after two months in two new courses. After eight months it was found that the highest accuracy achieved was 95%; this varied by professor and course material. The stenographer was able to improve her accuracy as her familiarity with the professors and the course material increased. Another benefit of the RTGD system is that the transcripts are saved on disk and can be printed out as hard copies of class lectures. These can be distributed to all interested students.

In a second study at RIT, Stinson et al. (1988) investigated students' perceptions of the RTGD system in the classroom. They surveyed 121 students who are deaf or hard of hearing who took classes at RIT over a 3-year period. The students had other accommodations available to them, including trained notetakers, tutors, and ASL interpreters. Students were very pleased with the RTGD system. Overall, they reported that the RTGD system allowed them to understand 80% of the classroom material, while they understood 61% of the material with ASL interpreters. When asked which support service they would choose (if they could choose only one) 32% selected the RTGD system and 21% selected ASL interpreting. It appeared that students with better English oral skills preferred the RTGD system and students with better ASL skills preferred the ASL interpreter.

The RTGD system, which has been used successfully in the classroom, would seem ideal in the workplace as well. Stenographers can attend meetings on an as-needed basis. The stenotype machine can transmit directly to a notebook computer that contains the real-time-translation software, and the computer can be positioned so the person who is deaf or hard of hearing can read the material on the monitor As this technology becomes increasingly available, professional court reporters are becoming informed and excited about the new job opportunities available to them (Moody, 1995; Task Force on Realtime Reporting in the Classroom, 1995). Two major problems may limit the usefulness of using stenographers in the workplace: the availability of stenographers on short notice for occasional work and the high cost associated with stenographers traveling to the workplace.

A possible solution to the high cost and availability of stenographers would be to work with stenographers at a remote location. The stenographer could listen to the meeting through a speakerphone and transmit the transcription through a modem. This could reduce the cost of the stenographer's time, because the stenographer would not have to travel to the workplace, thus reducing travel time and travel costs. In addition, stenographers could be more available for work in a situation such as this, due to the decreased travel time. If this system became widely used, stenographers could be available on a phone-in basis, just as relay service operators are available to interpret telephone conversations using Telecommunication Devices for the Deaf (TTYs).

There are, however, several concerns about the usefulness of CART in the workplace. One problem with this system is that at the present time it is quite cumbersome for a person who is deaf or hard of hearing to set up. It requires that a conference telephone system be connected to one outside phone line and a notebook computer hooked up to a second phone line. If new technology is not easily accessible it may not be used in the workplace (Sokol, 1994). A second concern regarding the usefulness of CART was brought up during the researchers' informal discussions with professional stenographers; stenographers report that it is difficult to understand meetings though conference telephone systems when more than two people are speaking. If the transcription service is only accurate for small meetings, this would severely limit the usefulness of this system. A third concern regards the use of stenographers who are unfamiliar with the speakers and/or jargon used in a meeting. If transcription accuracy is only adequate for familiar speakers and topics, this also limits the usefulness of the CART system

The purpose of the present investigation was to determine the feasibility of the CART system in the workplace. This was accomplished with an experiment and a case study. In the experiment, a professional stenographer transcribed meetings from a remote location (listening over a conference telephone) and from within the meeting room, while the number of speakers in the meeting varied from 2 to 10. The purpose of this experiment was to learn whether the accuracy of the stenographer's remote transcription would decrease as the number of people in the meeting increased. The stenographer transcribed two meetings from the remote location and two meetings from within the meeting room. The multiple-session design allowed us to investigate practice effects on transcription accuracy. In the case study, the usefulness and practicality of the CART system was investigated for a professional who is deaf in the workplace.

METHOD Participants

Eight doctoral students and two faculty members in the Graduate Program in Speech and Hearing Sciences at the City University of New York participated in the meeting. The stenographer was a Registered Professional Reporter, certified at 225 words per minute.

Meeting

The topic of the meeting was "Graduate studies in audiology and speech pathology." All speakers were given agendas that listed discussion topics. The meeting was led by the first author. Prior to the meeting, the stenographer was given the agenda, a list of all the meeting speakers, and a list of technical terms related to audiology and speech pathology that, based on the agenda, might come up during the discussion.

Four separate sessions were held. During the first and the fourth sessions, the stenographer listened to the meeting over a conference telephone from a remote office. These two sessions were considered to be Trial 1 and Trial 2, respectively, for the remote location. In the second and third sessions, the stenographer was inside the meeting room. These two sessions were considered to be Trial 1 and Trial 2, respectively, for the meeting-room location. Each session consisted of five 5- to 10-minute blocks. During each block of time, 2, 4, 6, 8, or 10 speakers participated in the meeting. The order of the blocks was randomized within each session.

When the stenographer was at the remote location, the meeting speakers were asked to identify themselves by name before they spoke. Speakers also were asked to be sure that they were within three feet of one of the conference telephone microphones and to move the telephone module closer if necessary. When the stenographer was in the room, he sat at the same table as the speakers and was able to see most of the speakers' faces most of the time.

Equipment

The conference telephone was a Shure ST3500 ConferencePhone Teleconferencing System. This consists of a telephone interface box, an acoustic module, and two expansion modules. The telephone interface box supplies power to the system and interfaces between the acoustic module and the telephone and power outlets. The acoustic module consists of a keypad, a loudspeaker, and three condenser microphones. One or two expansion modules can be connected to the acoustic module via 8-foot cables; each expansion module contains three condenser microphones.

The stenographer used a stenotype machine (Stenograph) connected to a notebook computer. The computer ran realtime software (Eclipse by Advantage), which translates the phonetic symbols from the stenotype into English (Advantage, 1997). The realtime software contains a personal dictionary that includes the phonetic inputs for a basic list of English words. Each stenographer modifies the personal dictionary to translate his or her personal stenotype shorthand. During realtime transcription, the realtime software searches first the personal dictionary then the job-specific dictionary for an English word to match the phonetic input. The software also uses grammatical knowledge to resolve conflicts when selecting appropriate English words.

The stenographer added the agenda information, proper names, and technical terms to his job-specific dictionary before the meeting. The transcript of each session was saved on disk in text format. The transcripts were printed out later for analysis.

Each session was videotaped. This provided a visual and an audio record of the meeting. The videotape was used to determine the accuracy of the stenographer's transcription.

RESULTS

The word-by-word accuracy of the stenographer's written transcript was verified by comparing it to the videotape of the corresponding session. A "percent-correct" score for each spoken phrase was calculated. A minimum of 50 phrases was spoken in each block within each session. Therefore, we analyzed the first 50 phrases in each block. We found a high degree of variability in the stenographer's performance. The data was collapsed in two ways prior to the statistical analysis to decrease the variability of the data and, therefore, prevent spurious findings. Within each block, performance for the first 25 phrases was averaged together and considered replication one, and performance for the last 25 phrases was averaged together and considered replication two. Within each session, performance for the listening blocks with 4 and 6 speakers was averaged together, and performance for the listening blocks with 8 or 10 speakers was averaged together.

The percent-correct scores were subjected to an arcsine transform to stabilize the error variance prior to an analysis of variance. We performed a fourway fixed effects ANOVA; the main effects were replication (first or second), trial (first or second), location (remote or in the meeting room), and number of speakers in the meeting (2,4-or-

6, or 8-or-10). The results were collapsed across the factor, replication, so this factor is not shown in the ANOVA table; the results of the ANOVA are shown in Table 1.

The main effects of location and number of speakers were significant. Follow-up tests were conducted using the Tukey HSD test with a .05 significance level. For the main effect location, the stenographer's accuracy was significantly poorer when he was listening from the remote location compared to when he was listening from within the meeting room. For the main effect number of speakers, accuracy with 2 meeting speakers was significantly better than accuracy with either 4-or-6 or 8-or-10 speakers. When there were more than 2 speakers, there was no tendency for decreased performance as the number of people in the room increased.

The untransformed percent-correct scores were transformed into error rates to ease visual comparisons; these are shown in Figure 1. The significant main effects found in the ANOVA analysis are apparent in the figure. The first block of four bars, (performance when there were 2 speakers) show the smaller error rate compared to the second and third blocks of bars, (when there were 4-or-6 or 8-or-10 meeting speakers). Within each set of bars, the first two bars (the remote location) almost always showed a higher error rate than the second two bars (the meeting-room location).

Another trend that was apparent in the figure is that, within each group of bars, the first bar was always higher than the second bar. This demonstrated that when the stenographer was listening remotely his error rate decreased during the second trial. It appeared that over time the stenographer became familiar with the speakers and the topics of conversation, and his performance improved. This improvement over time was not apparent when the stenographer was inside the meeting room. The tendency for improved stenographer accuracy as a function of the listening trial approached significance in the ANOVA analysis.

Analysis of the transcripts revealed two types of errors: (a) Words or phrases were omitted, or (b) Word or phrases were transcribed inaccurately. These two types of errors occurred with similar frequency across all four sessions. Many of the omitted words were repeated words or words that were not crucial for meaning; however, the stenographer did attempt to transcribe every word, regardless of meaning. When words or phrases were transcribed incorrectly, this was the result of one of three types of errors: (a) The stenographer heard the speech material incorrectly and transcribed the wrong words (hearing errors), (b) The stenographer entered the information correctly or one key off, and the words were translated incorrectly by the stenographer's software (mistranslate errors), or (c) The stenographer entered the information correctly, but the words were not in the realtime software dictionaries and could not be translated (untranslate errors). Examples of these three types of errors are shown in Table 2. Most of the errors were technical terms or proper names. Hearing errors occurred when the stenographer typed an incorrect phonetic symbol. He heard the word incorrectly, probably due to room noise, a reduced speech level, and/or the absence of visual cues. Because the words were often technical words or proper names the stenographer was unable to use contextual information to determine the correct word. Mistranslate errors often occurred when the stenographer made a fingering error, pressing the wrong phonetic symbol during transcription. The realtime software then translated the wrong word. When this occurs, the realtime software often interprets the word boundaries incorrectly. For example, as shown in Table 2, the word normals became norms always. Untranslate errors occurred when the stenographer typed the correct phonetic symbols but the realtime software did not contain the term in its dictionary so it could not translate the word into English. Some errors were difficult to classify exactly, so we did not include them in the error classification. Certain errors that appeared to be mistranslate errors actually could have been the result of hearing errors. Of all types of errors, hearing errors appeared to occur most frequently. Approximately 48% of all errors were hearing errors when the stenographer was in the remote location and 37% were hearing errors when the stenographer was in the meeting room.

CASE STUDY

The CART system was used over an 8-month period by a person who is deaf who holds a management position in a large corporation. This participant was prelingually hearing impaired and is fluent in both English and ASL. He participated frequently in meetings of various sizes with coworkers who had normal hearing. He used ASLinterpreters at meetings, but at times he had difficulty scheduling an interpreter. In addition, some of the interpreters he used were inexperienced, and he felt that their accuracy was unacceptable for his needs.

The participant used the same Shure conference phone that was used in the experiment. The transcription was set up to be received on a Gateway 2000 Liberty notebook computer equipped with a 14.4 PCMCIAmodem. Initially, two pieces of software were installed for the CART system. Norton pcANYWHERE (Symantec) is communication software that allowed the notebook computer to communicate with the stenographer's computer. This software ran on both the deaf participant's computer (the alternate computer) and the stenographer's computer After a modem connection is made, the software allows the alternate computer to "enter" the stenographer's computer. Therefore, everything that is seen on the stenographer's screen (the transcript of the meeting) can be seen on the alternate computer. The deaf participant also has a visual impairment, so MAGic 2.0 (Microsystems software) was installed, which doubles the size of the type displayed on the screen.

After the third attempt to use the CART system ended in failure, new software was used. The stenographer ran Legal Assist (Eclipse) communications software along with the realtime software; this permitted an ASCII output of the text. The participant received the ASCII output with REMCAN (remote computer-assisted notetaking), a DOS program developed at the Technology Assessment Program at Gallaudet University. In addition to receiving the ASCII output, it allowed the participant to control the scroll speed, the type size, and the typeface and to save the transcript to a file.

The participant and two of his assistants took part in several training sessions to learn how to use the equipment. They were instructed to ensure, prior to using the service, that the conference room had two single-line analog telephone jacks that they could use, one phone line for the conference telephone system and one phone line for the notebook computer. Because they worked in a large corporate office building, they had an in-house technical staff that could install phone lines on short notice. The participant and the assistants received written, step-by-step instructions regarding the use of the telephone system, the computer hardware and software, and the setup of the conference room.

The participant was given the following list of information that the stenographer covering each meeting would need: a list of all the meeting speakers, a meeting agenda, and a list of all technical terms that might be used in the meeting. This allowed the stenographer to enter the proper names and technical terms into the personal dictionary in the realtime software so they could be translated correctly from the phonetic shorthand. The participant also was told how the meeting should run to maximize the stenographer's understanding over the conference telephone system. He was told to ask meeting speakers to identify themselves each time they spoke, not to speak when someone else was speaking, and to keep the table clear of large objects (to allow for maximal sound transmission to the telephone system's microphones).

A summary of the participant's nine attempts to use CART is shown in Table 3. The first five attempts to use the system were unsuccessful; these were the result of preparation problems, software problems, and hardware problems. Preparation problems resulted from users' unfamiliarity with the setup of the telephone and computer systems.

Software problems were due to the incompatibility of the pcANYWHERE and the MAGic software packages. The hardware problems resulted from the modem's incompatibility with the phone line and from incorrect installation of the modem. After switching to new software and receiving new instruction on the use of the equipment, the participant finally had success with the system. Some problems persisted, however; these problems mostly resulted from the user's unfamiliarity with the equipment and the CART procedures.

Following each hookup, the stenographer and the deaf participant completed questionnaires about their impressions of the service. The participant had two major positive reactions to the service:

1. He felt that the transcription was quite accurate. In general, he felt that he was receiving the transcription with 85% accuracy. The participant felt that this accuracy was far superior to the accuracy he received with ASL interpreters. With ASL interpreters, he often felt that important information was lost in translation.
2. The hard-copy transcript of the meeting provided through this service was valuable because it provided a substitute for the notes the participant could not take while he was using an ASL interpreter, lipreading, or using the CART service.

The participant had two major negative reactions to the service:

1. He reported that, in a busy work environment where conference rooms are at a premium, it was difficult to schedule the extra time necessary to setup the CART service.
2. The system was not ideal for quick-paced discus, ions, due to the 2-to 3-second time lag. The participant always felt behind in the meeting discussion.

The stenographers reported that they were frustrated with the participant's insufficient familiarity with the procedures. They were not always given the list of the speakers prior to scheduled meetings, or they were given incomplete lists. The meeting speakers did not follow conference telephone etiquette, such as identifying themselves before speaking. Despite this, the stenographers consistently reported that they understood 85 to 95% of the meeting over the conference telephone system.

DISCUSSION Transcription Accuracy

The accuracy of the transcription was quite good. During the first session when the stenographer was out of the room and listening remotely, accuracy ranged from 87% correct when there were 2 people in the room to 78% correct when there were 6 people in the room. Overall performance was 83% correct in the first session. By the fourth session, when he was again listening remotely, the stenographer had become familiar with the speakers and the material being discussed. Performance in the fourth session ranged from 92% correct when there were 2 people in the room to 87% correct when there were 4 people in the room; overall performance was 89% correct in the fourth session.

Stuckless (1983) reported transcription accuracy of 90% correct for a stenographer in a classroom after two months of experience in the setting. The stenographer in the present experiment achieved comparable accuracy after 2 hours.

Based on the present results, CART can be accurate for meetings of up to 10 speakers. Transcription accuracy will vary according to the skill of the stenographer However, it is likely that accuracy will improve as a stenographer works with the same client. This allows the stenographer to add to her or his personal dictionary and to become more familiar with the jargon and the speakers at a particular work setting. In addition, transcription accuracy is influenced by the quality of the conference telephone system and by how the meeting is conducted. Transcription accuracy should be greater for meetings in which speakers introduce themselves before they speak and take hams in speaking and where background noise is minimal.

Ease of Use

Sokol (1994) discussed what could be done to make implementing and using new technologies less frustrating. He pointed out that usability testing helps people modify problems and identify potential future enhancements. The usability testing conducted in the case study identified several problems and possible solutions.

Many of the problems were due to the cumbersome procedure required to set up the CART system. It often was difficult for the participant to arrange for a room with two properly installed single-line analog phone connections. New technologies are becoming available that should solve this problem. Modems are available that can transmit data and voice over the same telephone line. Once these are shown to be reliable, they can be used for CART. Another option is wireless communication. The conference telephone and/or the notebook computer could be adapted for wireless communication.

Other problems encountered in the case study were caused by software that was not designed specifically for CART use. To enhance communication between the stenographer and the system user, new software can be developed that both transmits and receives realtime transcription.

CONCLUSIONS

For CART to be a useful tool in the workplace, the system must be easy to set up and use, and it must allow for accurate, error-free transcription. If people who are deaf or hard of hearing are to rely on this service, they must be able to set it up, have confidence that it will work, and trust the transcription accuracy. This study demonstrated that, after a limited time for stenographer familiarization, users should be able to trust the transcription accuracy. However, the case-study results demonstrated that a more user-friendly hardware and software system is required.

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Table 1. Results of the Analysis of Variance

Legend for Chart:

A - Source
B - Degrees of freedom
C - Mean square
D - F ratio
E - Level of significance

A	B	C	D	E
Trial	1	.06	3.59	.0796
Location	1	.15	8.71[*]	.0118
Trial x location	1	.05	3.00	.1061
No. of speakers	2	.13	7.25[*]	.0087
Trial x no. of speakers	2	.02	1.11	.3610
Location x no. of speakers	2	.02	1.37	.2902
Trial x location x no. of speakers	2	.03	1.74	.2155
Residual	12	.02	--	--

* $p<.05$

Table 2. Errors in Transcription

Legend for Chart:

A - Type of error

B - Actual phrase
C - Transcribed phrase

A	B C
Hearing	This is good enough for a second level project. This is good fluff for a technical project.
Hearing	That's dichotic listening. That's psychotic listening.
Mistranslate	We tested a whole bunch of normals about 5,000 times. We tested a bunch of norms always about 5,000 times.
Mistranslate	... then we decided to try it out. ... then we design today try it out.
Untranslate	I don't know if the electrophysiology testing ... I don't know if the electric TROE physiology testing ...
Untranslate	I don't think that's dichotic, I think it's monotic. Not die cot EUBG, Monday on the EUBG.

Table 3. Case Study Outcomes

Attempt	Outcome	Reason for negative outcome
1	Failure	Preparation problem
2	Failure	Preparation problem
3	Failure	Software problem
4	Failure	Hardware problem
5	Failure	Hardware problem
6	Partially successful	Insufficient user familiarity with procedures
7	Success	--
8	Partially successful	Hardware problem and insufficient user familiarity with procedures
9	Success	--

GRAPH: Figure 1. Mean error rate as a function of the number of participants.

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Welcome

The primary purpose of the Communication Access Information Center is to provide information of use to people employing or in need of Communication Access Realtime Translation (CART), also known as realtime captioning. The site is sponsored by the National Court Reporters Foundation and supported by the National Court Reporters Association's CART Task Force. Click here for information on what NCRA is doing to increase the number of available CART providers.

What Exactly Is CART?

Communication Access Realtime Translation (CART) is the instant translation of the spoken word into English text using a stenotype machine, notebook computer and realtime software. The text appears on a computer monitor or other display. This technology is primarily used by people who are late-deafened, oral deaf, hard-of-hearing, or have cochlear implants. Culturally deaf individuals also make use of CART in certain situations. Please keep in mind that CART is also often referred to as realtime captioning.

The Americans with Disabilities Act specifically recognized CART as an assistive technology which affords "effective communication access." Thus communication access more aptly describes a CART provider's role and distinguishes CART from realtime reporting in a traditional litigation setting.

Communication Access Realtime Translation is an evolving and maturing profession, and the available technology associated with CART is rapidly advancing. Consequently, the information and guidelines listed here will be updated from time to time. Please check in often.

CART in the Classroom: Meeting the Communication Access Needs of Students Requires an Individual Approach

Students with hearing loss who have access to assistive technology such as CART are provided with the same opportunities to learn and grow as hearing students. This growing technology allows the student to take an active role in the classroom and meet his or her potential as a scholar. (PDF format) More...

Benefits of CART

CART Environments

Digital Hearing Aids

CAIC Home

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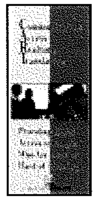
NCRA Develops New Certifications for CART and Captioning

With Congress appropriating millions of dollars in order to establish and strengthen realtime writing programs, CART and captioning have increased in popularity as a profession. Schools receiving federal funds will train writers in order to meet the mandates set in the Telecommunications Act of 1996, which requires all new television programming to be 100 percent captioned by 2006 and allows greater CART access to those with communication access needs. More...

New Brochure Helps Consumers Market CART



Are you looking for a tool to help explain CART to those who will decide whether or not the service will be provided? If so, NCRA's new CART marketing brochure, "CART: Providing Equal Access to People Who Are Deaf or Hard of Hearing," might be just the thing you're looking for. The brochure offers a brief definition of CART, the many environments where it can prove effective, the benefits of employing this communication access service and where to go for more information.

Click here to view an Adobe version of the brochure. To purchase copies, call 800-272-6272 (TTY 703-556-6289 or msic@ncrahq.org) or visit the NCRA Online Store at www.NCRAonline.org.

NCRF/AJF Introduce Model Guidelines for CART in the Courtroom

To provide continuity in the provision of CART services in the legal setting, the National Court Reporters Foundation and the American Judges Foundation have developed model guidelines for the use of CART in the courtroom that offer a structure from which courts can draw in order to meet their individual circumstances. Courts can then manage the accessibility of CART services for people with hearing loss in a uniform and effective manner, benefiting both the court and the CART consumers. View the model guidelines.

How to Locate a CART Provider

If you're in need of CART, whether for the classroom, a doctor's visit or any other setting, here are some of the variables you need to consider when selecting a CART provider. You'll also find links to the two primary online directories of CART providers.

What Are the Benefits of CART in the Classroom?

The following paper, CART in the Classroom: How to Make Realtime Captioning Work for You, presented at the Instructional Technology and Education of the Deaf symposium at the National

Technical Institute for the Deaf in June 2001, explains the benefits of CART for students who are deaf or hard-of-hearing in an educational setting. The paper also discusses how CART providers can work effectively with instructors and coordinators of services to ensure that students with hearing loss receive the best communication access possible.

Researcher Aaron Steinfeld wrote his dissertation on the benefits of captions in the classroom setting. When he presented this information at a convention of the Alexander Graham Bell Association for the Deaf and Hard of Hearing (AG Bell), he was inundated with requests on the studies he used as starting point. He has allowed us to reprint this essay, in which he lists a number of those references, for the use of people who are petitioning for the use of CART in the classroom.

Meeting the Communication Needs of Children in School

The Individuals with Disabilities Education Act (IDEA) addresses the needs of children with disabilities. The following FAQ explains the procedure that should be undertaken for obtaining CART or some other communication access service in the education setting from elementary school through high school. Check out our IDEA FAQ as well as our State Education Agency Listings.

Meeting the Communication Needs of Postsecondary Students

Although CART is recognized in the Americans With Disabilities Act as an assistive technology which affords "effective communication access," obtaining CART service at some universities and colleges can often prove to be a challenge. Here are some resources that can help in your efforts to obtain CART in the postsecondary setting.

CART Legal Decisions

Check in to see the latest legal decisions affecting the terms under which CART is provided.

About NCRF

The National Court Reporters Foundation supports the court reporting and captioning professions through philanthropic activities funded through charitable contributions. Learn more about NCRF by visiting their web site.

About NCRA

NCRA is a 27,000-member nonprofit organization representing the judicial reporting and captioning professions. Members include official court reporters, deposition reporters, broadcast captioners, providers of realtime communication access services for deaf and hard-of-hearing people, and others who capture and convert the spoken word into information bases and readable formats. Additional information is available by calling 800-272-6272 (TTY 703-556-6289), visiting NCRA Online, or via email.