# HUMAN FACTORS AND SPEECH TECHNOLOGY: REFLECTIONS ON 20 YEARS OF USER INTERFACE DESIGN FOR SPEECH-ENABLED APPLICATIONS

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This paper reflects on the author's career of over 20 years as a user interface design specialist working in the area of speech-enabled applications. It provides a summary of the progress made and the challenges still to be met so that the technology can achieve its potential. In addition, this paper discusses some of the author's recent work in designing speech applications so that they will be more accessible to older adults and people with disabilities. This includes work in establishing national and international technical standards for user interface design for applications targeted for the public at large.

## 1. HUMAN FACTORS AND SPEECH TECHNOLOGY

In 1983, when this author entered the field of speech technology, the first applications were just being fielded and the few human factors specialists in the field were grappling with significant user interface design challenges, many of which still exist. The technology was limited, largely, to small-vocabulary discrete speaker-independent speech recognition systems, though the first applications of connected and/or continuous speech recognition were appearing on the horizon. In the United States, the American Voice Input/Output Society had been established with the primary goals of educating the public about the potential of the technology and publicizing some the first real-world applications,

From the beginning, speech recognition was advertised as a technology that could solve the problems of the hands-busy, eyes-busy worker, and industrial applications of speech recognition, like inventory control, were among the first to be fielded. The U.S. military establishment was also interested in speech technology to assist pilots with very high visual and manual workloads. One of the author's first applied research projects, supported under the military's ambitious Advanced RotorCraft Technology Integration (ARTI) program, which was intended to produce a windowless military helicopter designed to be flown with the assistance of both speech recognition and synthetic speech technologies.

Although some of these first applications were successful, many were not. Training of speaker-dependent recognizers was an arduous process, noise was a significant issue affecting recognition rates for many applications, and problems like extraneous speech at the beginning of utterances decreased speech recognition accuracy in practice. Although some developers publicized recognition rates of 95% in laboratory settings, accuracy in practice was often much less. In addition, error correction of speech input was never efficient, and this problem continues to explain why commercial speech dictation systems today have achieved only limited success in the marketplace. Error correction of typed input is still much faster error correction via speech, for most users.

In the late 1980s, the industry appeared to enter a period of frustration. Technologically, there had not been breakthroughs significant enough to advance speech technology in practice and meet end user

expectations. While speech scientists concentrated on improving speech recognition accuracy and achieving the goal of continuous, large vocabulary speech recognition, it appeared that the technology had been brought to market before it was ready. End users rejected speech recognition, because they expected and wanted not speech *recognition* systems, but speech *understanding* systems – systems that could engage in a two-way dialogue with a human user, with some semblance of "intelligence." They wanted conversational systems that could manage and deal gracefully with the common irregularities of human-to-human communication – a tall order to be sure. The period of the late 1980's and early 1990's, thus, represents a low point with respect to the application of speech technology in practice, and some wondered whether speech technology would ever really be viable in the marketplace.

Nevertheless, the speech technology picture was not altogether negative. Although speech recognition may have hit a temporary plateau in terms of application, progress in synthetic speech was significant. Synthetic speech systems were now available in a number of languages, and the intelligibility was excellent. The systems still sounded, clearly, like machines, but each year, as our understanding of speech and, particularly, prosody increased, synthetic speech systems were introduced that sounded more and more like human beings. In the United States, this paved the way for the development of interactive voice response (IVR) systems that employed synthetic speech output coupled with touch-tone user input. The possibility of removing the human operator from the customer service loop was extremely attractive to U.S. businesses, and interactive voice response systems became ubiquitous long before the work had been done to determine how such applications ***should*** be designed to best serve customers. As a result, there was little standardization across applications, and many poorly designed applications were implemented that frustrated users and led to the coinage of terms like "voice mail jail" to describe the user experience of getting completely lost in a poorly designed IVR application. Because touch-tone phones were not in widespread use in Europe, the European community was fortunate to "skip" this evolutionary step in speech application design to a large degree. However, the next logical evolutionary step in IVR systems, when technological strides in speech recognition occurred, was to speech-enable the input to IVR systems, which is now occurring. Unfortunately, substituting speech recognition input for touch-tone input has not improved these systems, because the problems lie not with the technology, but with the design of the user interface.

In terms of user interface design, the IVR systems that became commonplace in the U.S. in the late 1980s and early 1990s were menu-based – a simple attempt to transfer a visually-based dialogue system to an auditory medium. In so doing, designers ignored the fact that speech is different from vision in numerous ways, perhaps the most important being its transient nature and its demands on human memory. Menu-based dialogues were not "natural" for an IVR application, which provides no visual context or visual cues. As a result, users became lost in the dialogues and confused by menus with too many options that they couldn't remember. In addition, many applications were designed with no appreciation of the user's context or constraints, which led to many logic failures in dialogue design. Nevertheless, business is business, and telecommunications applications of speech technology became the industry leaders and a basis for much of the speech technology market in the 1990s and into the present century.

In the mid-1990s, speech recognition achieved the breakthroughs for which many in the industry had been hoping. Large vocabulary speech recognition systems became a reality, speaker-independent systems increased the potential for widespread publicly available applications, training of speech recognition systems became simpler, if not unnecessary, and problems like filtering of noise and handling of extraneous speech were being solved across numerous applications contexts. Shrink-wrapped speech dictation software packages became available. Work in natural language processing was beginning to have an impact on the design of speech applications. Security concerns across the world were providing an impetus for work in speaker identification and verification. Commercially viable applications were being implemented across domains from business (stock quotations) to medicine (medical transcription) to transportation (speech control of vehicles and automated route guidance systems).

In the U.S., the American Voice Input/Output Society became more globally focused and changed its name to the Applied Voice Input/Output Society (AVIOS) in the late 1990s. Its mission also changed from one of education and demonstration of the potential of the technology, to one of support for application developers. The Society had established, in 1984, an applied journal that was produced in-house with limited distribution, but in 1995 contracted with Kluwer Academic Publishers to establish the journal as the

*International Journal of Speech Technology*, which was and is the only journal with an applied focus in the speech technology field. Over the past several years, AVIOS has been working to become a membership organization with chapters. It now has chapters in several major U.S. cities, and has established a chapter in Israel, as well. The intent is to foster communication and networking among applied speech professionals, regardless of their particular business or research focus.

During the past several years, the world has seen the introduction of speech-enabled IVR applications and web-based applications employing speech. A few years ago, Microsoft launched its Speech Server at a major industry meeting in California, with the claim that one could now quickly speech-enable any application. What Microsoft didn't say was that although one might be able to speech-enable any application, that didn't mean one would necessarily do it well, or that the speech-enabled version would work as well for customers as the original application.

The turn of the century has brought increasing globalization to the speech technology marketplace, as advances in communications and information technology bring us all closer together. Automatic translation of one language to another no longer seems like an impossible goal, and we are now bringing the power of speech technology to assist with tasks like database search and retrieval. The development of true conversational user interfaces employing speech technology, however, remains a challenge. Although we can develop speech applications that attempt to carry on a graceful dialogue with a user, only the simplest of such applications succeed. Human-to-human communication is a complex endeavor; achieving human-machine communication in the form of natural language dialogues (i.e., conversations) will require a fuller understanding of conversational language and the human communication process that may yet be decades away.

## 2. USER INTERFACE DESIGN FOR IVR APPLICATIONS

As noted previously, touch-tone-based IVR applications became commonplace in United States before guidance was written to assist designers in developing applications that served users well. It was not until 1996 that an international standard was promulgated for the design of voice messaging user interfaces [1], and this standard probably had limited impact, given that so many systems were already in use. In addition, the standard was limited to guidance related to voice messaging systems, specifically, and did not address user interface issues for the broader class of IVR applications.

In 1997, a small group of members of the Human Factors and Ergonomics Society in the United States decided to work on the development of a guidance document for IVR interface design, generally. Although it was targeted at touch-tone based IVR systems, given that speech-enabled IVR systems were just beginning to be introduced, its guidance was written at a sufficiently high level that it could apply to speech-enabled systems as well as touch-tone-based systems. This document was published as an Human Factors and Ergonomics Society ANSI canvass draft in 2000 [2], and comments were solicited from users.

The draft was amended based on the feedback received and was recently approved through the ANSI canvass process with comments as one section (200.4) of larger standard on software user interface design (ANSI/HFES 200) [3]. The comments on this document have been addressed, and the document will be released for a final vote of the canvass committee in the spring of 2007.

There are currently no international standards on IVR user interface design, though the need for such standards has been recognized. Recently, a working group of the International Standards Organization (ISO) – ISO TC159 SC4 WG5 (Software Ergonomics) – decided to pursue standardization work in this area, using the HFES document as a starting point for a new standard. Hopefully, the guidance produced as a result of these efforts will help to improve the design of IVR user interfaces in the future.

## 3. USABILITY AND ACCESSIBILITY OF SPEECH USER INTERFACES FOR PEOPLE WITH DISABILITIES

Much has been written in the U.S. press about the distinct lack of user friendliness of IVR applications – both speech-enabled ones and touch-tone ones. Typical users have difficulty navigating these applications and meeting their goals. Furthermore, many such applications now constitute the only way to obtain

customer service from a company or organization. Although it is supposedly possible to reach a human customer service representative and opt out of an IVR application while on the phone, one needs to know the command for contacting a human being, and most IVR applications do not tell one how to do so. Highly frustrated by this situation, a man named Paul English made headlines in U.S. news in late 2005 when he investigated the IVR applications of a large number of U.S. companies to discover the commands that would allow a caller to reach a human customer service representative, and promptly published the entire list of those commands on a web site (www.gethuman.com). This has produced some embarrassment in the industry and has led to a renewed interest in improving IVR application designs, initiated at the grassroots level by consumers. Mr. English' web site now contains some basic design guidance similar to that found in HFES 200.4. Similarly, Walt Tetschner, who publishes the industry newsletter, *ASR News*, routinely berates the industry for claiming to provide customer service, on the one hand, and designing applications that don't work on the other.

When Microsoft introduced its Windows-based operating system many years ago, it made computers almost completely inaccessible to blind users for a period of time, until assistive technologies were developed to counteract the problems. Similarly, IVR systems have been a major source of frustration to users who are deaf, or who have hearing or speech impairments. In the U.S., many people who are deaf use telecommunication devices for the deaf (TDDs or TTYs) that employ a relatively slow half-duplex communications protocol called Baudot, where the user on one end of the line cannot send information at the same time that the user on the other end of the line is sending information. This situation made it very difficult, if not impossible, for TTY users to utilize IVR systems, because the system would time-out before the user could receive the information from a prompt and reply to it. AT&T has developed solutions that allow IVR systems to work effectively for TTY users, but many IVR application developers do not utilize the technology and fail to recognize the problem these systems pose for deaf users.

When the Human Factors and Ergonomics Society initially released the DSTU on IVR user interface design, it contained no explicit accessibility guidance, and numerous comments about incorporating such guidance were received from members of the IVR Forum of the Alliance for Telecommunications Industry Solutions (ATIS). As a result, he draft was revised to incorporate specific guidance for making IVR systems accessible, not only to deaf users who use TTYs, but to other users with disabilities for which IVR systems, as currently designed, are problematic. The final version of the HFES document contains this specific guidance [4].

With respect to TTY users specifically, the HFES 200.4 document specifies that applications should inform TTY users as to whether touch-tone input, Baudot input, or both are accepted by the application software. It also specifies that prompts and announcements for TTY users should contain the same content as those for non-TTY users, but should be formatted differently, because there are abbreviations and communication conventions employed by TTY users specifically, and deaf users generally, that justify treating TTY messages as a separate language. Because of this, the document also recommends that TTY users be consulted during the development of prompts and announcements for user with TTYs. Finally, the guidance specifies that messages sent to a TTY via am IVR system in situations where service is delayed should be frequent and varied in their wording, so the user knows that the system is operating and he/she is still connected to the application.

Other accessibility-related guidance is intended to assist users who may have physical or cognitive impairments that make it difficult for them to use IVR systems. For example, HFES 200.4 specifies that users should be required to input information only once during the course of a call. The application, in other words, should be able to use the information input by the user any time during the call, without asking the user to re-enter the information. This promotes usability and accessibility for people with physical disabilities, for whom the additional physical effort of re-entering data may be a burden. Similarly, for users with physical or cognitive disabilities, who may be apt to make frequent mistakes when using an IVR system, the guidance specifies that users be given ample opportunity to change or correct information that has been previously entered during the call.

Much of the accessibility guidance, if applied during the design of IVR applications, would increase the usability of those applications for general users, as well as those with disabilities. For example, HFES 200.4 specifies that

1) context-sensitive help should be provided;

2) language and terminology use should be consistent throughout an application, and jargon should be avoided;
3) prompts and lists of options should be recorded or synthesized so that the voice pitch is lowered at the end of the prompt or at the end of the list as a cue to users that their input will soon be required;
4) caller key presses should be minimized;
5) ordering of list options should be prioritized, based on frequency of use, importance, logical order, or other factors of importance to callers;
6) feedback should be provided after every caller input;
7) users should be able to replay portions of long prompts and announcements; and
8) the audio quality of prompts and announcements should be as good as possible, and the volume consistent across the application, to assist users with hearing impairments in using the application.

## 4. OLDER ADULTS AND IVR SYSTEMS

In several countries throughout the world, including the U.S. and, more notably, Japan, populations are aging. In Japan, for example, approximately 19% of the population was over the age of 65 in 2003, and by 2015, the expected percentage is 26% [5]. In the U.S., the percentage is currently smaller (about 12%), but expected to be 20% by 2030 [6]. Both countries are discovering that significant numbers of older adults are having difficulty maintaining their independence because of problems created by technology that was designed by and for younger adults, whose capabilities and limitations are different.

Older adults are the most variable of all age groups in terms of their capabilities and limitations. Some live to be very old with minimum physical, sensory, or cognitive declines, while others acquire significant deficits in one or more areas. That said, however, all older adults experience some physical, sensory, and cognitive changes as a consequence of *normal* aging that can impede their use of technology. For example, in the area of vision, older adults generally experience increased susceptibility to glare [7], decreased contrast sensitivity [8], a decline in color vision [9], and a decrease in the size of the peripheral vision field [10]. They may have difficulties with visual search tasks, especially when the number of items to be searched increases [11].

With respect to audition, older adults experience hearing losses in both the high frequency range and in the speech range. The typical older adult loses about 2.5 dB per decade until age 55, after which the rate of loss increases to 8.5 dB per decade, with men losing more of their hearing than do women [12]. Auditory temporal resolution also decreases with age, and this directly impacts the perception of speech [13]. Older adults will often have difficulties understanding speech when listening in less than optimal environments, for example, over the telephone [14]. Older adults have greater difficulty ignoring irrelevant information sources when processing information from another relevant source. They also require more time to switch their cognitive processing from one auditory source of information to another [15]. All of these findings have implications for the design of over-the-phone applications intended for use by older adults.

There are also numerous cognitive changes that occur during the normal aging process that should be considered when designing IVR applications. Short term memory declines with age, and there is a general "slowing" of cognitive processing. In addition, although adults certainly can and do learn new tasks and skills, the time required to do is greater than for younger adults, even when those tasks are simple [16]. Older adults are more apt to get lost in complex procedures and lose their place in sequences [17], and they have more difficulty carrying out two tasks at the same time, than do younger people.

From a physical standpoint, task performance is slower [18], and reaction times are slower to stimuli that require a response. Most of the increase in reaction time can be attributed to choosing the appropriate response, rather than to perceiving the input or physically responding to it [19]. Interestingly, in some instances, reaction time differences between older and young adults disappear when the response required is vocal, as opposed to manual [20].

We know from testing IVR applications specifically with older adults that they experience significant difficulties navigating these applications and successfully completing the tasks involved, so much so that they opt out of the applications (if that is possible) or rely on others to make calls when they know they will be faced with an IVR application. Many of their difficulties can be traced to the changes described above that

occur as a consequence of the normal aging process. The end result is that a considerable portion of the population is unable to use these applications.

Although many changes occur with age, perhaps the single most important change with implications for IVR design relates to the need for more time to process information, to make decisions, and to execute responses. IVR applications that place time constraints on responses create many of the problems older users experience. For example, one Medicare health care claims IVR application in the U.S. requires users to enter a very long claim number at the beginning of the call, but gives the caller very little time to make the entry. As a consequence, some older users are only able to enter the first several digits before being told that their entry is incorrect. IVR applications, therefore, would be much more easily used by older adults if they removed time limits from the application or, if such time limits are necessary, were smart enough to gracefully provide the user with the option to request more time, given that the application "knows" the user is in the process of entering the requested information.

The second mistake many IVR applications make that creates problems for older users is providing too much information at one time via excessively long prompts or very long lists of response options. This places a burden on the caller's short term memory that can cause confusion and/or incomplete understanding of the information in the prompts or lists. Thus, it is important for IVR application developers to strive to make their applications as clear and simple as possible, minimizing the amount of information provided that does not relate directly to the tasks the caller is likely to be performing.

One of the reasons IVR applications may serve older adults so poorly is that these applications are not often tested with older users before being released in the field. IVR applications intended for use by older adults should be tested with a significant number of older people before being implemented. Greater numbers may be needed than for the typical usability test because this population is so highly variable in its capabilities, limitations and task performance.

Finally, it should be noted that many of the difficulties experienced by older adults using IVR applications are entirely and easily preventable. Older adults are not the problem; nor are limitations of the technology itself. The problems lie with the implementation and user interface design. By understanding the issues and following the guidance in documents like ANSI/HFES 200.4, user interfaces to these applications can be improved. The likely result will be better, more effective, IVR applications, not only for older adults, but for all users, and a better reputation for the IVR industry.

## 5. OTHER STANDARDS RELEVANT TO DESIGNING FOR OLDER USERS AND PEOPLE WITH DISABILITIES

Much of the author's recent work has involved the development of technical standards related to the use of technology by older adults and people with disabilities. Given the aging of populations in many countries of the world, and the number of people with disabilities who have special needs, it is important to raise public awareness of what can be done to improve technology so that it works for everyone.

In addition to the U.S. IVR standard (ANSI/HFES 200.4) that will hopefully soon be followed by a parallel ISO standard, there are several ongoing efforts within ISO to develop standards and technical reports to assist developers in designing products, systems, and applications that better meet the needs of older consumers and people with disabilities.

ISO TC159 SC4 WG5 – Software Ergonomics, in addition to taking on the task of developing an international version of the U.S. IVR standard, has developed a significant standard on software accessibility, generally – ISO 9241-171 [20]. This standard was recently approved via an international ballot, and is in the process of being finalized. It covers accessibility of all software, and one of its goals is to serve as input to drive software accessibility legislation in Europe, particularly. There is a parallel U.S. version of ISO 9241-171 – ANSI/HFES 200.2 – that is nearly identical in content, though it is not intended to drive legislation, given the U.S. already has legislated software accessibility in other documents [21] [22]. Because ISO 9241-171 covers software generally, it can and should be applied to speech recognition products and applications.

Another working group organized directly under ISO TC159 – WG 2-Ergonomic Requirements for People with Special Needs – has recently balloted successfully a Technical Report (DTR 22411) intended to

provide general guidance and ergonomic data for standards developers to use in specifying design requirements for any product, service or system to meet the needs of older adults and people with disabilities [23]. This technical report is organized according to the framework on disabilities and design provided in another ISO document, ISO Guide 71 [24]. Because the scope of DTR 22411 is so broad, much of the guidance is general, but the document may be quite useful for designers and standards developers who have had little exposure to the ergonomic/human factors issues involved in designing for older adults and others with special needs.

Finally, it should be noted that there are many documents being developed within ISO related to accessibility – so many that a joint ISO/IEC Technical Committee (JTC-1) has established a Special Working Group on Accessibility (SWG-A) that is tracking the various efforts and attempting to do gap analyses to determine areas in which additional standardization is needed. In addition, it has developed a User Needs Profile that augments the information in ISO Guide 71 with additional needs of users with disabilities that should be met in the design of systems, products, and services.

It is hoped that the work of all these groups will, over time, raise the consciousness of those who apply the technology so that it works in practice for everyone.

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