The Ongoing Evolution of Standards to Meet the Needs of the Deaf and Hard of Hearing

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The recent publication of three documents by the International Organization for Standardization (ISO) evolves the previous understanding of the needs of deaf and hard of hearing computer users. This paper explores these new documents and their recommendations for this group of users. The implications of these new guidelines and their relation to other standards are also discussed.

INTRODUCTION

The recent publication of ISO 9241-171, ISO 9241-20, and the User Needs Summary of the ISO/IEC JTC1 Special Working Group on Accessibility (SWG-A) each provide guidance and understanding to support the needs of users with disabilities and improve the accessibility of technology. These documents, among others, provide new understanding of accessible computing systems for all users.

However, the focus of guidelines to support accessible design has typically been towards users with text disabilities. The needs of other groups have not always been addressed to the same degree. Two populations of users whose needs and expectations have historically been poorly understood are users who are deaf and users who are hard of hearing (HH). This paper briefly explores the history and evolution of guidance on accessible software design to support the full inclusion of deaf and hard of hearing (D/HH) users with an emphasis on documents produced by the International Organization for Standardization (ISO).

BACKGROUND

Historically, guidance to assist developers and system procurers to meet the needs of D/HH users has focused on the provision of visual cues for audio alerts (e.g., ShowSounds – a system level flag that applications use to provide captioning and visual equivalents to any auditory events – see Vanderheiden, 2004). While this meets some of the needs of people who cannot hear, it represents an oversimplification.

Vanderheiden's *Considerations in the Design of Computers to Increase their Accessibility by Persons with Disabilities* (1988) was one of the earliest documents to provide an understanding of the needs of D/HH users. Focusing on visual cues to support the needs of the D/HH, it proposed that audio output be provided in visual form. Since individuals who are deaf cannot use information (e.g., tones, voice, clicks, etc.) presented in audible form, this guideline recommended information required for system operation and error detection also be provided in an "appropriate" visual form (Vanderheiden, 1988). However, audiovisual training materials were specifically exempted since they are not "required for operation" even though few people could use a computer or its software without extensive training at the time.

Vanderheiden (1988) proposed that audio output be adjustable and "available in a clear form" for amplification. However, while recommending that sound volume be adjustable to aid HH individuals, it did not recognize that, for many HH people, simple amplification alone is not enough (Nadol, 1993).

The *Nordic Guidelines for Computer Accessibility* was originally published in 1993 and then fully updated with the release of a second edition in 1998 (Thorén, 1998). Like Vanderheiden (1988), the Nordic Guidelines noted that while D/HH people have little difficulty using computers, they need visual output that is "complementary" to audio output. Thorén proposed that:

- System signals (e.g., alarms) should have:
  - alternative forms (auditory, visual, and tactile),
  - in the case of audio signals, have adjustable volume, pitch and frequency, and,
  - in the case of visual signals, be placed where easily perceived,
- Electromagnetic characteristics should not interfere with hearing aids, and
- Hardware noises should be minimized since they may be annoying or interfere with conversation.

The first point recognizes that, for many HH people, simple amplification alone is not enough. The other two note that electromagnetic noise (e.g., buzzing from cell phone interference) and acoustic hardware noise (e.g., fans) are barriers for the HH. The third recognizes that hearing aids amplify the entire environment (Dolan & Maurer, 1996).

The Nordic Guidelines began to move our understanding of the needs of D/HH users beyond visual cues by recognizing that people who are deaf may use a signed language as their first language and, as a result, the written language used in dialogs will likely be their second language. However it did not suggest what to do about this and left it as, "an issue to be taken into account by the dialogue designer." (Thorén, 1998).

This implies that dialog designers must attend to the needs of second, or other, language users. This is not just an issue of internationalization or cultural access, but a key accessibility requirement to meet the needs of deaf signers for whom signed

languages may be their first (or most comfortable) language.

In the mid-1990's, the Human Factors and Ergonomics Society's HFES/ANSI 200 committee began developing accessibility standards based largely on the Nordic Guidelines and identified new areas of accessibility requirements. In 1998, their work to date was submitted to ISO committee TC159 / SC4 / WG5 *Software Ergonomics and Human Computer Dialogue* as the basis for international work on software accessibility standardization. This led to the development and publication of ISO Technical Specification (TS) 16071 *Guidance on accessibility for human computer interfaces*, which recognized that the needs of the D/HH include (ISO, 2003):

- Individualizing audio output attributes such as frequency, volume, speed, and "sound content",
- Establishing specific frequency ranges for non-speech audio,
- Using at least two strong mid- to low-frequency components within specific low/high frequency ranges to ensure HH users will detect alerts and other auditory warnings, and
- Enabling users to control whether alerts are presented visually or auditorially.

The first point introduces the idea that users might want to change the sounds associated with events and notifications. Such customizations could be used by HH users to help ensure they can detect or distinguish different alerts.

The second and third points recognize that users who are HH have individual differences in their perceivable range(s) of hearing. Some cannot hear in low frequency ranges, others cannot hear in high frequency ranges, still others experience gaps in each range.

The fourth point recognizes that users should not have accessibility features imposed upon them. Instead users should have the ability to choose whether to use a specific feature. Developers who recognize that preference settings may have accessibility implications and consequently provide as much opportunity to customize as possible create more accessible software. For example, most operating systems (OS) provide tools for users to change sounds associated with events and notifications. Software that provides its own sound effects should give users the ability to customize those effects. In addition, users need to be able to denote whether notifications are visual, auditory, or both.

While ISO TS 16071 builds upon the recommendations of the Nordic Guidelines, it ignores the impact of the environment on hearing. Further, given that the most common hearing loss is such that high frequency hearing is often worse than low frequency hearing (Nadol, 1993), the frequency ranges suggested by ISO TS 16071 (e.g., "between 500 Hz and 3000 Hz", ISO, 2003) may be too high for the majority of HH users. Finally, large numbers of the 71 guidelines in ISO TS 16071 were narrowly focused on a relatively small number (of the many potential) abilities and skills of users. These and other criticisms suggest a number of key areas that needed further attention, especially in areas supporting D/HH users (Carter & Fourney, 2004).

Thus, guidelines primarily developed in the 20th century evolved from simply acknowledging that D/HH users have some difficulty hearing sounds, to recommending the implementation of visual alternatives to audio output and user control of these alternatives. Only the Nordic Guidelines recognized the needs of hearing aid users and the need to support signed languages. Notice that, although the technology existed, there was no guidance on captioning in any of these documents.

DEVELOPMENT OF ISO 9241-171

ISO 9241 is a series of standards concerned with the ergonomics of computers. Part 171, which focuses on the accessibility of software, evolved from ISO TS 16071 and contains a large amount of new content not found in its predecessors. Canada proposed several new guidelines specific to the needs of D/HH users (Carter & Fourney, 2003). In particular, unlike its predecessors, ISO 941-171 includes guidance on captioning (ISO, 2008b):

Display any captions provided. D/HH users need access to the same spoken and other auditory information that other users have.

Enable system-wide control of captioning. Users need to be able to control the presentation of any information, including both how information is presented and whether or not the information is displayed. If users have access to captioning, they should be able to control that captioning.

Support system settings for captioning. Many OSes have global settings enabling users to turn on all captioning or other supports for D/HH users in one place. Often, software applications do not adhere to these settings and consequently do not automatically display any captions or other visual cues. However, even if an OS does provide such a global setting, users must always have the ability to control whether a specific application displays captions.

Position captions to not obscure content. Users need to be able to control where captions and other visual cues are displayed. This ensures that alternative content, such as captions, does not obscure information important to the user's tasks. However, there is no guidance in ISO 9241-171 to ensure captions are not obscured.

No current ISO standard states how captioning should be presented and there is little agreement on the most effective design. For example, in North America, it is common to see capitalized white mono-spaced text on a black background, while other regions commonly use color and mixed case.

Rather than just ensure audio output is "available in a clear form" (Vanderheiden, 1988), ISO 9241-171 recognizes the need for HH users to control all sound content. It includes updated versions of the ISO TS 16071 frequency shifting guidelines and recommends that users be enabled to control background and other sound tracks since background sounds such as so-called "mood music" interfere with the ability to hear speech.

To control all audio channels, multimedia must be designed to allow the emphasis of the information content (e.g., speech dialog). This may require enabling users to

reduce or mute the volume of any background sound as well as to change the volume of the foreground sound rather than just one volume control for all sound.

Thus, guidance on captioning and audio channel control in ISO 9241-171 shows that the needs of D/HH users extend beyond flashing lights and window titlebars to include multimedia. In addition, general guidance to meet the needs of other users with disabilities is now more likely to include consideration of the needs of D/HH users. For example, "Update equivalent alternatives for media" ensures every update of a multimedia presentation includes updates to the captions. Note, ISO 9241-171 also includes information on conformance that requires software be tested to ensure that it is fully accessible for D/HH users.

DEVELOPMENT OF ISO 9241-20

While ISO 9241-171 is explicitly focused on software accessibility, ISO 9241-20 is a high level systems and services standard that applies to both hardware and software.

ISO 9241-20 specifically recommends that products support users who cannot hear or who have limited hearing. It has several guidelines which have direct analogues in ISO 9241-171 including:

- providing visual cues for alarms and alerts,
- providing volume control,
- enabling users to adjust audio frequencies, and
- enabling users to control the volume of soundtracks, especially background sounds.

It provides two new recommendations suggesting that the needs of D/HH users also include (ISO, 2008a): avoiding harmful audio, and having information presented visually.

Avoiding harmful audio. Although avoiding loud sudden noise is a safety issue for all users, many HH users are particularly concerned because of their current experience of hearing loss (e.g., Canadian Hard of Hearing Association, n.d.). This implies that designers need to support the hearing health of users through tools that monitor sound volume output. HH users in particular are not always aware that they have set their speakers / earphones to a too loud volume.

Providing verbal information visually. While analogous to the ISO 9241-171 guideline that requires providing alternative formats, this recommendation goes beyond using just text or captions to include the use of sign languages.

ISO 9241-20 is the first ISO standard on accessibility to specifically recommend that designers consider providing information in a signed language. While not all D/HH people are fluent in a signed language, those who are may experience signed content as easier to understand than text. However, one of the challenges in meeting this guideline is that there is no universal sign language and even in large spoken/written language communities (e.g., all English speakers), there can exist multiple sign languages (e.g., American Sign Language, Australian Sign Language, British Sign Language, etc.). Developers should consider / research the sign language communities of their target audience.

Since many D/HH people have difficulty producing intelligible speech, developers cannot rely on the availability of clear speech for applications requiring speech recognition. ISO 9241-20 has specific recommendations that support both users with speech disabilities as well as D/HH users. All of these recommendations suggest enabling support for the use of a keyboard or other text entry device (ISO 2008a).

ISO 9241-20 shows further evolution in our understanding of the needs of D/HH people. It reintroduces the need to support sign languages, recognizes the need to protect hearing health, and ensures accessible alternatives are provided for speech recognition systems that meet the needs of D/HH users and users with speech disabilities.

THE USER NEEDS SUMMARY

The *User Needs Summary* (UNS), a document prepared by the ISO/IEC JTC1 SWG-A, describes, in general terms, a variety of user-specific needs (ISO/IEC, 2007). The scope of the UNS is very broad and extends beyond computer hardware and software. It provides a starting point for the analysis of existing standards to determine if gaps may exist as well as a foundation for future standards to ensure completeness. The UNS shifts our focus to identifying capabilities (i.e., needs) rather than technology solutions (i.e., designs).

The UNS has sixteen categories of user problems and needs (ISO/IEC, 2007). Of these sixteen, nine specifically discuss the needs of the D/HH. (The needs of the deaf-blind, which are beyond the scope of this paper, are also discussed). The UNS does not provide any explanation or rationale for any of its suggested user needs. The next seven sections are titled according to each relevant category. Two categories ("Perceive status of controls and indicators" and "Be able to invoke and carry out all actions") are not discussed because these needs have already been examined.

Perceive auditory information

This category identifies three new problems:

People with any disability cannot differentiate state if the same alternative is provided for different signals. Many D/HH users employ signaling devices that vibrate rather than flash. The UNS specifically recognizes that when vibration is used as a substitute for different auditory events, then some users need them to have different vibration patterns (i.e., rather than vibration frequency or strength) for different signals.

This has implications for the redesign of visual cues so that different flashes are provided for different signals since current tools (e.g., ShowSounds) give the same window or titlebar flash regardless of the nature of the alert.

People who are hard of hearing may miss any information presented auditorially because:

- ***it is at a frequency they cannot hear,***
- ***background noise blocks it or interferes with it (including echoes),***
- ***it is too soft,***
- ***it includes poor quality speech, or***
- ***the speech is too fast and user cannot slow it down.***

Many HH users have difficulty discriminating sounds. In addition to the ability to adjust the volume to a suitable level or the need for auditory events and alerts to be "multi-

frequency", users might need the ability to pause and re-play / repeat information presented using audio (Fourney, 2007). Developers should always provide multimedia controls and not hide them because such controls are necessary for access.

People who are hard of hearing might not be able to perceive information presented in stereo. Many HH users have hearing capabilities that are one-sided (i.e., so-called "single-sided deafness") such that information typically encoded in stereo (e.g., location of sound) cannot be perceived or understood (Fourney, 2007). Consequently, the UNS recognizes that some users may need multi-channel auditory information available in monaural form. This impacts both the playback of stereo music and the meaningfulness of "surround sound". Designers should avoid using stereo sound alone to encode information and, when stereo is used to represent information, always provide visual alternatives.

The UNS evolves our understanding of the needs of D/HH users by recognizing that alternative signals need to be properly designed and that not everyone can hear in stereo.

Perceive feedback from operation

This category reintroduces two user problems:

- *People who are HH often cannot hear auditory feedback due to volume, frequency used, background noise, or speech feedback that is not clear or repeatable.*
- *People who are deaf cannot hear auditory feedback.*

D/HH users may need feedback to be tactile (i.e., both non-visual and non-auditory). Any subtle tactile feedback should have a visual or auditory alternative. The UNS recognizes that users benefit from feedback that is simultaneously multi-modal (i.e., visual, auditory, and tactile). Thus, our understanding of meeting the needs of D/HH users has now evolved to not just using visual cues and audio controls but also ensuring a combination of all modalities.

Have equivalent security and privacy

This category identifies two new problems:

People who are deaf may not detect sensitive information being said aloud. The UNS does not recognize that this issue also impacts HH users.

To address this user problem, the UNS suggests that some users need, "Private listening capability when using audio alternatives to visual information in public places." This will not completely solve this user problem because D/HH users need a non-auditory indication that an auditory equivalent to visual information is active. Such a visual cue could then also help a user to mute any auditory output.

In addition, the problem is only half resolved since D/HH users may choose to interact with a system through speech. If users do not detect that they are speaking too loudly, sensitive information may be easily overheard. Designers should ensure speech input systems include an indication of the speaker's volume in relation to the system's preferred speaker volume.

People who are hard of hearing may not realize volume of audio output. HH users may require louder volume of audio output. This may allow eavesdropping (even when the user is wearing earphones) compromising the user's expectation of security and privacy. To address this user problem, the UNS suggests that some users need, "Private listening capability when using audio alternatives to visual information in public places."

The UNS is the first of these documents to discuss the impact of disability on privacy. Designers should consider privacy requirements when designing for accessibility.

Not cause personal risk

This category identifies a new problem:

People who are deaf or hard of hearing may miss sounds that indicate imminent device failure. D/HH people may not detect alert tones and may attempt to operate a device when unsafe. Thus some users need products where hazards are "obvious and easy to avoid" as well as "difficult to trigger". In addition, some users need to be able to use products safely without hearing hazard warnings. This need implies that all products be designed with multimodal hazard indicators.

Understand how to use product

This category reintroduces the user problem:

- *People who are deaf may have a different first language (e.g., a sign language) than the spoken/written language used on the product (e.g., English, etc.).*

Although Thorén (1998) recognized this need, there was no suggestion on what to do about it. The UNS suggests some users need the wording, symbols, and indicators that are used on products to be as easy to understand as possible, and information and feedback be "salient" and "specific" rather than subtle or abstract to understand it. Further, text needs to be as clearly and simply worded as possible such that even information presented using figures of speech (e.g., abbreviations, idioms, metaphors, etc.) are presented in a way that does not require understanding the figures of speech.

The UNS also suggests that products use culturally (and, if possible, cross-culturally) standard conventions, words and symbols to help address this user problem. This evolves our understanding of the needs of D/HH users by introducing the need to be culturally sensitive to these populations and recognize that they are different from both the larger majority hearing population in which they exist and each other (e.g., Laszlo, 1994; Padden & Humphries, 2005).

Understand the output or displayed material

This category identifies a new problem:

People who are deaf can have difficulty with simultaneous presentation of visual information and (visual) captions of auditory information. For D/HH users, the visual modality is very busy. Captioning, flashing windows, and other visual cues designed to provide D/HH users alternative means to auditory information can both help and hinder users at the same time due largely to the "busyness" of the visual modality. To counter potential cognitive or visual overload, the UNS suggests careful design since some users may need visual information generated by access features (e.g., captions) to not occur simultaneously with other visual information users must

view. This concern lends further support for the need to communicate certain information via tactile cues.

Ability to use assistive technology

This category identifies two new problems:

People who are deaf (and some who are hard of hearing) cannot access auditory information if it is not available to their* [assistive technology (AT)] *(which they must use) in machine readable form through a standard connection mechanism. The UNS suggests that some users need, "full and efficient functional control of a product using their AT, including pass-through of user feedback and notifications" (e.g., error messages).

People who are hard of hearing need all audio information to be available via a standard connection mechanism that is compatible with their assistive listening devices (ALDs). Products designed for HH users need to provide a standard audio connector to plug-in an ALD. Further, products requiring something to be held up to the ear need to be compatible to a hearing aid's telecoil (or T-Coil). A telecoil is a very small coil of wire built within a hearing aid that serves as an antenna for an induction loop or telephone receiver (Ross, 2004).

Thorén (1998) made clear the need to not interfere with the operation of hearing aids but had little need to support multimedia. Although it does not mention the need to not interfere with the operation of hearing aids, the UNS recognizes that HH users may want to use their hearing aids when accessing audio content. Thus, designers should consider how their products may be used in conjunction with hearing aids. For example, some earphones can be uncomfortable to wear because they press hearing aids into the wearer's skull.

CONCLUSION

Recent documents such as ISO 9241-20, ISO 9241-171, and the UNS show a broader understanding of the needs of D/HH computer users.

The information gathered in these three documents will impact the development of other standards both within and without the domain of software design. In particular, the Web Content Accessibility Guidelines (WCAG) 2.0 (Caldwell, Cooper, Reid, & Vanderheiden, 2008) is being evaluated in terms of the problems and needs identified in the UNS (JTC 1 SWG-A Secretariat, 2007).

There remain several future directions for new understanding of the needs of D/HH users. Two examples are voice output and captioning.

Although, by definition, HH users are more likely to use voice output than the deaf, they will have specific needs for natural sounding (rather than artificial sounding) voices, control of output (e.g., repeat, rephrase), and simultaneous presentation of alternatives (e.g., captioning). An improved understanding of the voice output needs of D/HH users will impact ISO standards yet to be developed relating to such products (e.g., interactive voice response systems (IVR)).

Work is still needed to identify new guidelines in the area of captioning. Several of the above guidelines suggest providing captions, however there are no guidelines on what these captions should look like, how they should be used, the degree to which they should be accurate, and so on.

The lists of guidelines discussed in this paper show that D/HH users have greater needs and expectations than just visual cues. Greater control over existing audio output and access to tactile cues can increase access and usability for this user group. Designers are strongly encouraged to incorporate these guidelines into their products.

REFERENCES

Caldwell, B, Cooper, M., Reid, L., & Vanderheiden, G. (2008). *Web Content Accessibility Guidelines 2.0 (W3C Candidate Recommendation 30 April 2008)*. http://www.w3.org/TR/2008/CR-WCAG20-20080430/

Canadian Hard of Hearing Association (n.d.). *Noise annoys...It also damages your hearing* [brochure].

Carter J., & Fourney, D. (2003). *The Canadian position regarding the evolution of ISO TS 16071 towards becoming an International Standard* (ISO TC159 / SC4 / WG5 Document N0731).

Carter, J., & Fourney, D. (2004). Using a universal access reference model to identify further guidance that belongs in ISO 16071. *Universal Access in the Information Society*, *3*(1), 17-29. http://www.springerlink.com/link.asp?id=wdqpdu5pj0kb4q6b

Dolan, T., & Maurer, J. (1996). Noise exposure associated with hearing aid use in industry. *Journal of Speech and Hearing Research*, *39*(2), 251-260.

Fourney, D. (2007). *Canadian National Body contribution towards the evolution of the User Needs Summary* (JTC 1 SWG-A N 240). http://www.jtc1access.org/

ISO (2003). *ISO TS 16071: Ergonomics of human-system interaction – Guidance on accessibility for human-computer interfaces*.

ISO (2008a). *ISO 9241-20: Ergonomics of human-system interaction – Accessibility guidelines for information/communication technology (ICT) equipment and services*.

ISO (2008b). *ISO FDIS 9241-171: Ergonomics of human-system interaction – Guidance on software accessibility.*

ISO/IEC (2007). *ISO/IEC PDTR 29138-1 Information Technology — Accessibility Considerations for People with Disabilities — Part 1: User Needs Summary*. http://www.jtc1access.org/

JTC 1 SWG-A Secretariat (2007). *Final Draft Agenda for the 23-27 April 2007 Meeting of the JTC 1 Special Working Group on Accessibility (SWG-A) - Hamar, Norway* (JTC 1 SWG-A N 247). http://www.jtc1access.org/

Laszlo, C. (1994). Is there a hard-of-hearing identity? *Journal of Speech-Language Pathology*, *18*(4), 248-252.

Nadol, J. (1993). Hearing loss. *New England Journal of Medicine*, *329*(15), 1092-1102.

Padden, C, & Humphries, T. (2005). *Inside Deaf culture*. Cambridge, MA: Harvard University Press.

Ross, M. (2004, May 25). Telecoils deserve wider acceptance as assistive listening devices. *ASHA Leader*, *9*(10), 1, 30.

Thorén, C. (1998). *Nordic Guidelines for Computer Accessibility* (Second Edition). Nordic Cooperation on Disability. http://trace.wisc.edu/docs/nordic_guidelines/nordic_guidelines.htm

Vanderheiden, G. (1988). *Considerations in the design of computers and operating systems to increase their accessibility to persons with disabilities* [Technical Report]. Madison, WI: Trace R&D Center, 2107 Engineering Centers Bldg., 1550 Engineering Dr., Madison, WI 53706. http://trace.wisc.edu/docs/considerations/consider.txt

Vanderheiden, G. (2004). Information technology access research at Trace R&D Center. *Proceedings of CSUN Technology & Persons with Disabilities Conference*. http://www.csun.edu/cod/conf/2004/proceedings/291.htm