Supplement A

Texts included in the scoping review

|  |  |  |
| --- | --- | --- |
| Authors | Year | Publication Specifications |
| Experiment (n=29) | | |
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Supplement B

Study Designs and Experts’ Discussion Topics

Table 1. Design of Experimental Studies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Author (year) | Sample Size | Hearing Status | Independent Variables | Dependent Variables |
| Stoker (1981) | 300 | 100 moderately impaired  100 severely impaired  100 normal | Coupling method: amplified handset vs. magnetic vs. acoustic vs. tube microphone adaption  Level of background noise | Speech intelligibility in noise |
| Lowe & Goldstein (1982) | 10 | Bilateral, moderately-severe sensorineural hearing loss | Phone-hearing aid coupling method: acoustic vs. induaplanctive | Speech intelligibility |
| Holmes, Frank, Stoker (1983) | 30 | Normally hearing | Sidetone: present vs. absent  Background noise: multi-talker vs. white noise; intensity  Other ear: occluded vs. not occluded  Transmitter: occluded with hand to reduce sidetone vs. not occluded | Speech intelligibility in noise |
| Holmes & Frank (1984) | 45 | 15 with precipitous loss; 15 with gradually sloping loss; 15 with flat loss | Listening condition: earphone vs. unaided telephone, hearing aid acoustically coupled to telephone  Amplitude: 86 dB SPL vs. MCL | Speech intelligibility |
| Stoker, French-St. George, & Lyons (1986) | 36 | 12: moderate loss with precipitous drop  12: moderate loss with gradual slope  12: severe loss | Type of hearing loss  Telephone signal level  Phone position relative to telecoil | Speech intelligibility |
| Terry et al. (1992) | 16 | Average loss was mild sloping to moderately-severe | Telephone signal with vs. without frequency shaping; with vs. without compression | Speech intelligibility |
| Holmes (1985) | 19 | Bilaterally mild to moderately-severe | Listening level: 86 dB SPL (comparable to standard handset) vs. participant’s most comfortable level  Coupling: unaided acoustic, aided acoustic, aided magnetic | Speech intelligibility |
| Plyler, Burchfield, & Thelin (1998) | 8 | Mild to moderate hearing loss | coupling method: acoustic vs. electromagnetic | Speech intelligibility  Noise tolerance |
| Sorri et al. (2003) | 32 | Moderate to moderately-severe hearing loss | Telephone strategy: landline vs. cell phone vs. cell phone with induction loop | Speech intelligibility  Subjective evaluation |
| Lidestam, Danielsson, & Lonnborg (2006) | 10 | Hearing impaired | Mode of speech presentation: visual, vs. auditory vs. audiovisual  Visual contextual cues: present vs. absent | Speech intelligibility |
| Nakao et al. (2008) | 20 | Normal hearing | Type of earpiece: in-ear earphone with and without earplug; supra-aural headset  Level of background noise | Signal to noise ratio required for speech intelligibility Attenuation of background noise in the ear |
| Zekveld, Kramer, Kessens, Vlaming, & Houtgast (2008) | Exp 1: 24  Exp 2: 14  Exp 3: 25 | Normally hearing | Exp 1: presence vs. absence of automatic speech recognition (ASR) text output  Exp 2: presence vs. absence of ASR ‘confidence’ indicator  Exp 3: Degree of text delay | Speech intelligibility in noise  Readability of ASR output |
| Desjardins & Doherty (2009) | 50 | Experienced hearing aid users | Age | Scores on the practical hearing aid skills test (PHAST) |
| Mackersie, Qi, Boothroyd, & Conrad (2009) | 14 | Mild to moderately-severe | Standard phone setting vs. individualized amplification of phone signal | Phoneme recognition  Listening Effort  Sound quality |
| Zekveld, Kramer, Kessens, Vlaming, Houtgast (2009) | 20 | Average hearing loss: mild sloping to severe-profound | Automatically generated captions along with telephone speech: present vs. absent  Captions 60-70% accurate with log vs. 90% accurate with no lag | Task load  Narrative comprehension |
| Brault et al. (2010) | Exp 1: 31  Exp 2: 28 | Mild hearing loss  Normally hearing (controls) | Exp 1:  Hearing status  Lip-reading proficiency  Audio alone vs. audio and video  Telephone bandwidth or broad bandwidth  Time lag  Exp 2:  In white noise vs. in quiet | Speech intelligibility  Recall errors |
| Ferguson, Jongman, Sereno, & Keum (2010) | 60 | 20 normally hearing young adults; 20 normally hearing older adults; 20 older adults with hearing loss | Accent: speaker with vs. without  Signal: presented in quiet vs. in background noise  Telephone frequency bandwidth | Speech intelligibility |
| Mantokoudis et al. (2010) | 31 | Cochlear implant users; hearing aid users; normally hearing controls | Internet telephone signal (under ideal network conditions) vs. conventional telephone signal  Internet telephone signal (under ideal network conditions) vs. frequency constricted, uncompressed, cd grade signal | Speech intelligibility in quiet and in noise |
| Julstrom, Kozma-Spytek, & Isabelle (2011) | 57 | Moderate to profound hearing loss | level of interfering noise (s/n ratio) in telephone signal transmitted to hearing aids via telecoil induction | Subjective usability of signal |
| Picou & Ricketts (2011) | 20 | Mild sensorineural hearing loss | Telephone listening condition:  bilateral vs. unilateral signal presentation  noise level in open ear  occluding vs non-occluding hearing aid dome | Speech intelligibility |
| Mantokoudis et al. (2012) | 30 | Cochlear implant users; hearing aid users with moderate bilateral sloping losses, normally hearing control group | Hearing status  Signal to noise ratio  Telephone signal: traditional telephone vs. VoIP at 0%, 5%, 10%, and 20% packet loss | Speech intelligibility |
|  |  |  |  |  |
| Picou & Tivkryyd (2013) | 18 | Moderate to severe sensorineural hearing loss | Telephone strategy in noise: acoustic telephone vs. unilateral telecoil induction vs. unilateral wireless streaming vs. bilateral wireless streaming  Non-test ear aided vs. plugged | Speech intelligibility  Signal to noise ratio  Subjective ratings of ease and comfort |
| Campos, Bozza, & Ferrari (2014) | 74 | New and experienced hearing-aid users | New vs. Experienced hearing aid users | Scores on the practical hearing aid skills test (PHAST) |
| Carioli & Teixeira (2014) | 17 | 2 mild; 13 moderate; 2 severe | Baseline vs. 3 months after being fitted with hearing aids vs. 6 months after being fitted | Ability to perform instrumental activities of daily living |
| Kim et al. (2014) | 30 | Bilateral moderate sensorineural hearing loss | Signal from cell phone vs. loud speaker  Coupled with cell phone acoustically, or through wireless transmission  In quiet vs. in noise | Sentence and word recognition scores  Self-report satisfaction |
| Smith & Davis (2014) | 12 | Moderately-severe to severe hearing loss | Baseline vs. after being provided with Bluetooth devices (streamer, TV adaptor, remote control, and remote microphone) | Hearing disability  Hours of use |
| Ferguson et al. (2016) | Intervention: 103  Control: 100 | First time hearing aid users | Grouping: intervention group receiving online training in use of hearing aids vs. control group receiving care as usual  Time: baseline vs. post-course | Scores on the practical hearing-aid use test (PHAST).  Subjective scores of training modules’ usefulness |
| Wittich, Southall, & Johnson (2016) | 35 | Hearing and visually impaired; visually impaired with normal hearing | Visually impaired vs. visually and hearing impaired  Assistive device user is assigned to operate | Speed  Task Success |
| Kam, Sung, Lee, Wong, & Hasselt (2017) | 100 | Losses ranging from slight to moderate.  Normally hearing control group | Mobile device: with or without personalized amplification | Speech intelligibility  Subjective ratings |
| Ledda, Valente, Oeding, & Kallogjeri (2019) | Intervention: 20  Control: 10 | Experienced bilateral hearing aids users, loss ranging from slight to severe.  Normally hearing control group | Telephone signal presented through programmed vs default telecoil | Speech recognition |
|  |  |  |  |  |

Table 2. Design of Experimental Studies using Devices rather than Participants

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Author (year)** |  | **Device** | **Independent Variables** | **Dependent Variables** |
| **Fikret-Pasa & Garstecki (1993)** |  | Telephone amplifiers | Type of amplifier | Real ear frequency response curve |
| **Stinson & Daigle (2004)** |  | In the canal, in-the-ear, and behind-the-ear hearing aids hearing aids manufactured by Unitron | Handset proximity | Open loop transfer function (i.e., feedback) |

 Table 3. Design of Qualitative Research Studies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Author (year)** | **Sample Size** | **Hearing Status** | **Research Question** | **Methodology** |
| **Harris, Thomas, & Lamont (1981)** | 27 | Moderately-severe to profound hearing loss | How far would the proper use of certain aids contribute to a higher quality of life for both the hearing-impaired person and his or her family? | Interviews |
| **Pichora-Fuller (1981)** | 221 | Hearing impaired | Does the informant use the phone and if so, what problems do they have while doing so? | Open-ended mail surveys and telephone interviews |
| **Holmes, Kaplan, Yanke (1998)** | 19 | Hearing loss ranging from 28 to 66 dB SPL in better ear | What are the typical telephone use patterns of the subjects, and what are their comments, both positive and negative, regarding hearing aid compatibility with the telephone? | Open-ended mail surveys |
| **Iezzoni, O’Day, Killeen, & Harker (2004)** | 26 | Hearing impaired | What are the health care experiences of deaf and hard of hearing clients, and what suggestions exist for improving their care? | Semi-structured group interviews |
| **Ng, Phelan, Leonard, & Galster (2017)** | 8 | Hearing aid users | How do new innovations around connected hearing aids (i.e., wireless functioning) influence providers’ and clients’ experiences? | Collective case study drawing on interviews and grey literature |

Table 4. Design of Surveys

|  |  |  |  |
| --- | --- | --- | --- |
| **Author (year)** | **Sample Size** | **Hearing Status** | **Variables of interest** |
| **Kepler, Terry, & Sweetman (1992)** | 104 | 87% report moderate or severe loss  8.7% report profound loss  94% report bilateral loss | Problems encountered by the hearing-impaired population when using the phone and their coping strategies |
| **Scherich (1996)** | 252 | 77% hard of hearing  23% deaf | Difficult situations experienced by adults with hearing loss in the workplace  Workplace accommodations as reported by employees with hearing loss vs. employers  Employer demographics |
| **Geyer & Schroedel (1999)** | 232 | 69% deaf; 31% hard of hearing | Availability of workplace accommodations for hearing loss  Age, gender, educational level  Type of employer, employer size, occupational classification |
| **Bowe (2002)** | 884 | 64% deaf; 24% hard of hearing; 8% hearing; 4% no answer | Use of communication technologies (telecommunication devices for the deaf, telephone relay services, email, instant messaging)  Age, income, educational level  Open ended questions about technology |
| **Yoder & Pratt (2005)** | 41 | Hearing impaired | The use and importance of the telephone among adults with hearing loss  Telephone modifications and substitutions used |
| **Kaplan & Holmes (2010)** | 47 | Participants ranged from having a mild to moderately-severe bilateral sensorineural hearing losses | Preferred method of using the telephone among adults with hearing loss |
| **Iwahashi, Jardim, & Bento (2013)** | 200 | mild to moderately-severe bilateral sensorineural hearing loss | Interventions required by clients returning for one-year follow-up after hearing aids dispensed |
| **Maiorana-Basa & Pagliaro (2014)** | 278 | 12% mild or moderate  13% severe  More than half profound | Technology and websites used by deaf and hard-of-hearing Americans |
| **Ruppel et al. (2016)** | 1634 | Cohort with and without hearing loss | Frequency of contact with adult child (email, phone, face-to-face)  Depressive symptoms  Communicative difficulties  Control variables (e.g., proximity to adult child) |

Table 5. Experts’ Discussion of Technology and Strategies

|  |  |
| --- | --- |
| **Author (year)** | **Technology or Strategy Described** |
| **Johnson (1982)** | Amplified telephones  Portable handset amplifiers  Amplified and frequency-appropriate ringers |
| **Martin (1983)** | Telephone amplifier  Counseling from an audiologist |
| **Castle (1994)** | Amplified telephone  Email and fax machine  Requesting accommodation |
| **Garstecki (1994)** | Needs assessments before fitting assistive devices |
| **Holmes (1994)** | Amplified telephone handsets  In-line telephone amplifiers  Portable telephone amplifiers  Telephone with built-in amplifier  Acoustic coupling of hearing aids and telephone  Telecoil induction coupling of hearing aids and telephone  Assistive listening devices |
| **Compton (1996)** | Remote microphone  Messaging services |
| **Federal Communication Commission (2000)** | Wireline phones and volume control |
| **Palmer (2001)** | Telecoil |
| **Yanz & Preves (2003)** | Telecoil |
| **Kozelsky (2005)** | Counseling from an audiologist  Telephone demonstration centres |
| **Yanz (2005)** | Telecoil |
| **Vanderheiden (2006)** | Telephone volume control  Telecoil induction  Using speakerphone as an amplifier  Smartphones  Captioned phones  Mobile phones and ‘easy-mode’ |
| **Myers (2008)** | Telecoil |
| **Hernandez & Martin (2009)** | Wireless transmission of telephone calls to hearing aids |
| **Endres (2009)** | Captioned telephone |
| **Caissie & Tranquilla (2010)** | Repair strategies  Topic switching in conversations  Clear speech  Clear speech training |
| **Frazier (2010)** | Telecoil |
| **Ingrao (2011)** | Bluetooth  Proprietary dedicated wireless systems  Telecoil |
| **Hamlin (2011)** | Federal Communication Commission, Consumer Advisory Committee and the rules and regulations around communication |
| **Hamlin (2012)** | Hearing-aid-compatible mobile phones  Captioned telephone  Amplified phones |
| **Hamlin (2013)** | Captioned telephones |
| **Ingrao (2013)** | Amplified phones  Voice over Internet Protocol (VoIP)  Coupling of telephone and hearing aids  Communication strategies |
| **Kozma-Spytek (2013)** | Telephone relay  Stand-alone captioned phones  Internet protocol captioned telephone |
| **Nealon (2013)** | Amplified analogue telephones |
| **Ingrao (2014)** | Google plus (video-conferencing)  Amplified headset  Captioned phone  Wireless transmission of telephone calls to hearing aids  Listening and Communication Enhancement (LACE)  Requesting workplace accommodation for telephone use |
| **Spangler (2014)** | Near field magnetic induction  Far field transmission (e.g., Bluetooth) |
| **Atcherson, Franklin, & Smith-Olinde (2015)** | Acoustics and telecoil induction coupling of hearing aids and telephone  Hearing-aid/ mobile phone compatibility  Wire-line phones  Wireless streaming from phone to hearing aids  Captioned telephone  Video calls  Digitally enhanced cordless telecommunications |
| **Taylor (2015)** | Hearing-aid/smartphone compatibility |
| **Federal Communications Commission (2016)** | Hearing-aid-compatible mobile handsets |
| **Hamlin (2017)** | Internet protocol captioned telephone |
| **Hearing Loss Association of America (2016)** | Hearing-aid-compatible mobile handsets |
| **Federal Communication Commission (2017)** | Hearing-aid-compatible wireline and wireless telephones |
| **Hamlin (2018, Sept/Oct)** | America’s Federal Communications Commission and its administration of Internet Protocol Captioned Telephone Service |
| **Powers (2018)** | Streaming telephone signal through hearing aids via Bluetooth |
| **Hamlin (2018, Sept/Oct)** | New regulations from America’s Federal Communication Commission (regulates the telecommunications industry and its accessibility) |
| **Franck & Gregowicz (2019, Jan/Feb)** | Applications of Bluetooth Low Energy, including Made for iPhone hearing aids, hands-free Bluetooth for hearing aids, and android-based Audio Streaming for Hearing Aids |

Supplement C

Findings Relating to Amplification

|  |  |
| --- | --- |
| Author (year) | Finding or Recommendation |
| Holmes & Frank (1984) | For participants with hearing loss, listening at the ‘most comfortable level’ leads to better intelligibility than listening at the standard telephone volume. |
| Stoker, French-St. George, & Lyons (1986) | As the level of the telephone signal increases from 5dB below standard telephone output (80 dB SPL) to 20 dB above (105 dB SPL) Intelligibility increases for participants with hearing loss. |
| Fikret-Pasa & Garstecki (1993) | Different telephone amplifiers provide different levels of amplification from frequency to frequency. |
| Pichora-Fuller (1981) | 12% of 111 interviewed audiology clients reported that hearing aids helped then on the phone, while 60 out of 61 telephone amplifier users found them helpful. 78% of telephone amplifier users reported having no difficulty on the phone because of using the device |
| Geyer & Schroedel, (1999) | 53% of hard of hearing employees surveyed were found to have a phone amplifier |
| Kepler, Terry, & Sweetman (1992) | Of a sample of 104 people, most of whom experienced a moderate to severe hearing loss, 76% reported that the telephone signal was softer than they would prefer. 55% used hearing aids when speaking on the phone and 73% used a phone amplifier. |
| Kaplan & Holmes (2010) | Using an amplified phone alone was the second most common phone setup for 47 adults with PTAs between 30 and 70 dB. The most common strategy involved taking one’s hearing aids out and using the phone normally without any amplification. |
| Scherich (1996) | Telephone amplifier was the most frequently provided accommodation in the workplace (66% of hard of hearing employees reported using one) |
| Martin (1983) | Telephones amplifiers can provide an output sufficient for up to a 70 dB HL loss |
| Ingrao (2013) | Amplified phones can allow for personalized frequency tuning |
| Vanderheiden (2006) | By turning the volume up and switching to speakerphone, users can gain more amplification from their phone |
| Hamlin (2011) | Amplified phones can provide up to 50 dB of additional amplification. Standards encourage companies to label amplified phones for whether they are appropriate for a mild, moderate, or severe loss. |
| Nealon (2013) | Amplifiers are designed to be used with analogue phones, but many business places using digital telephones systems with which amplifiers are not compatible |
| Hamlin (2012) | With the Sorenson CaptionCall® an individual can input their audiogram into the phone to customize the output to their hearing loss |
| Johnson (1982) | Amplifiers can come built into the phone or be portable (i.e., are clipped onto the handset when needed). Clients can more easily hear the telephone ring through plug-ins that provide a louder or lower frequency ring. Alternatively, a microphone can be set up that when triggered by the sound of the phone ringing, turns a light on. |
| Holmes (1994) | Various types of telephone amplifiers exist. Amplifying handsets provide between 20 and 40 additional dB. In-line amplifiers can couple with hearing aids electromagnetically as well as acoustically. Built-in amplifiers can have helpful features, such as a low-frequency ringer, or ringer light. In the Unites States, there is a precedent of telephone amplifiers being considered a ‘reasonable’ workplace accommodation. |
| Atcherson, Franklin, & Smith-Olinde (2015) Ch.10 | Amplified phones generally have tone-specific amplification control (i.e., you can set them to provide more amplification in the high or low frequencies), as well as large buttons and a handset emitting a strong electromagnetic signal for telecoil induction. In addition, some American states provide these amplified phones at a reduced rate through the Telecommunication Equipment Distribution Program |
| Terry (1992) | 20 dB of amplification increases intelligibility by 13%, frequency shaping increases intelligibility by 11%, frequency shaping and amplification increases intelligibility by 25% |
| Mackersie, Qi, Boothroyd, & Conrad (2009) | Speech intelligibility and subjective ratings are higher in both noise and in quiet when a telephone’s signal is tailored to individual’s hearing loss, frequency by frequency |
| Kam, Sung, Lee, Wong, & Hasselt (2016) | Speech intelligibility increases by 8-10% in both quiet and noise when mobile devices telephone-speech output is amplified to match a person’s hearing loss. The majority of participants preferred their individualized amplification in forced choice scenarios |

Supplement D

Findings Relating to Background-Noise

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| Author (year) | Finding or Recommendation |
| Picou & Ricketts (2011) | Changing noise level in non-test ear did not impact intelligibility |
| Nakao et al. (2008) | Earplug style earphone led to attenuation of background noise ranging from 13 dB in low frequencies to 25 dB in high frequencies. Led to significantly lower signal to noise ratios required for 505, 90%, and 100% intelligibility (as compared to supra-aural headphones) |
| Picou and Ricketts (2013) | Intelligibility worse in higher levels of background noise (65 dB HL significantly worse than 55 dB HL). In 55 dB HL background noise, unilateral wireless better than unilateral telecoil induction (perhaps due to orientation challenges). Plugging ear did not improve speech recognition. |
| Mackersie, Qi, Boothroyd, & Conrad (2009) | Intelligibility decreased in the presence of background noise |
| Julstrom, Kozma-Spytek, & Isabelle (2011) | Telecoil ‘background noise’ come from electronics producing interference. Need 21 dB SNR for half to consider acceptable for normal use (30 dB SNR for 85% to report acceptable) |
| Pyler, Burchfield, & Thelin (1998) | Acoustic no better than electromagnetic in terms of background noise tolerance. However, noise tolerance was significantly improved when sidetone was disabled |
| Holmes, Frank, & Stoker (1983) | Word discrimination poorer in background noise. Multi-talker babble more problematic for word discrimination than white noise. Disengaging sidetone or occluding transmitter with palm significantly improves intelligibility at high levels of background noise |
| Holmes, Kepler, & Yanke (1998) | Background noise reported as a problem in hearing on the telephone by 47% of veterans with hearing loss |
| Kepler, Terry, & Sweetman (1992) | Of a sample of primarily those with moderate to severe less, 94% reported background noise to be a problem encountered when using the telephone |
| Palmer (2001) | Cell phones created a buzz when using telecoil induction setting, but this has largely been dealt with by hearing aid manufacturers; alternatively, users can purchase a neck loop that separates phone components from the hearing aids |

Supplement E

Findings Relating to Bilateral Listening

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| Author (year) | Finding or Recommendation |
| Picou & Ricketts (2011) | Compared to acoustically transmitting the signal from the phone to the hearing aid in one ear (i.e., acoustic coupling) sending the signal from the telephone to the hearing aids in both ears through wireless technology (i.e., bilateral wireless coupling) led to significantly better speech intelligibility. However, this was only seen in clients with hearing aids that did not allow sound to enter the ear naturally (i.e., had occluding ear tips) |
| Picou & Ricketts (2013) | Bilateral wireless routing results in better speech intelligibility than unilateral wireless routing, acoustic coupling, or telecoil induction |

Supplement F

Findings Relating to Captioned-Phones

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| Author (year) | Finding or Recommendation |
| Zekveld, Kramer, Kessens, Vlaming, & Houtgast (2009) | Captioning of phone calls when there was a lag and an accuracy rate of 60-70% did not lead to lower task load than audio alone. When lag was removed and when there is 90% accuracy, the task load is perceived as lower |
| Zekveld, Kramer, Kessens, Vlaming, & Houtgast (2008) | ASR captioning does improve speech recognition in noise threshold even at low ASR accuracy rates (20%) |
| Ruppel et al. (2016) | Email can be powerful: worse hearing associated with more depression for those with low frequency of email contact with child, but not with those with high frequency of email contact with child |
| Bowe (2002) | 2002 survey of deaf and HoH found that email and instant messaging used more frequently than TTY or relay. Allows for emoticons which convey emotion, also email is free, unlike TTY. However, they use these technologies less frequently at work, in part due to the nature of their jobs (e.g., teachers) |
| Maiorana-Basa & Pagliaro (2014) | 2014 survey of deaf and hard of hearing found that 88% use email, 75% use text messaging, and 70% rarely or never use TTY |
| Yoder & Pratt (2005) | Of 41 audiologists with hearing loss, 58.5% used email as a replacement for the telephone but only 2.4% reported that they always use substitutes rather than the phone |
| Brad Ingrao (2013) | If the phone call fails, try email, text or letter as a backup |
| Hamlin (2012) | Sorenson CaptionCall® is an internet based captioned phone. Users’ audiograms can be input to provide complementary amplification |
| Kozma-Spytek (2013) | Stand-alone captioned phones look and are used in the same way as regular phones. They connect to the regular telephone network but also connect to the internet (wireless or through wirelines). The internet provides captions, as generated by a communication assistant repeating the party’s speech and having it transcribed by automatic speech recognition software. This communication assistant is completely transparent. Minimum service standards ensure that communication assistants must answer 85% of calls within 10 seconds, communication assistants cannot intentionally alter or disclose the content of conversations, and the conversation must be relayed in real time.  FCC develops rules for provision of captioned telephone service and oversees a federal fund for it. Telephone relay services are funded by charges on telephone company’s subscribers’ bills, and tariffs on the company itself. No charge is paid by the person with hearing loss themselves. A spike in the use of captioned phones in 2012 led to emergency rules being implemented to control costs. The FCC made it clear that the service is for the hard-of-hearing and those with normal hearing should turn the caption feature off when using these stand-alone phones. |
| Hamlin (2017) | More people using captioned phones and less people using landline (funding fee comes from landlines) has led to funding problem for captioned phones. There may be a move away from communication assistants and towards direct automatic speech recognition. |
| Hamlin (2013) | Captioned phones allow people to use their voice and residual hearing, with the captions as back up |
| Endres (2009) | Types of CapTel®  Two line  Outdoing and receiving calls are automatically captioned  CA uses ASR (repeats into speaker)  CA on second line so the parties are directly connected  One line  User simply calls out for outgoing calls  Incoming calls: caller has to call toll free number, then input number of person with hearing loss  Available 24/7 in English  Phones available through state assistive equipment distribution programs  Web CapTel®  Captioned displayed on computer screen, call made through standard or mobile phone  Mobile CapTel®  Captioning on smartphone screen; Use headset to hear people (need headset because have to look at phone at the same time) |
| Atcherson, Franklin, Smith-Olinde (2015) Ch. 10 | CaptionCall® and CapTel® provide captioning services through proprietary phones that work in a manner similar to regular acoustic landline phones but are captioned through a high-speed internet connection |

Supplement G

Findings Relating to Internet-Based Telephony

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| --- | --- |
| Author (year) | Finding or Recommendation |
| Brault et al. (2010) | Participants presented with extended bandwidth did not perform significantly better than those presented with a telephone bandwidth in the first experiment, but there was a significant improvement in the second.  Participants with hearing loss performed significantly better when they had video along with the audio, this was particularly the case for strong lip readers  Longer lags between audio and visual led to higher error rates  No benefit of bimodal stimulation on working memory performance  Bimodal display reduced perceived workload |
| Mantokoudis et al. (2010) | Better intelligibility in quiet and noise for internet protocol speech (as compared to traditional telephone speech). Internet protocol speech perception not significantly more intelligible than CD grade speech with the same restricted bandwidth as telephone speech. |
| Mantokoudis et al. (2012) | VoIP provides HA users with the greatest intelligibility when no packets are lost. Intelligibility is significantly better than traditional telephone when no packets are lost. There is no significant difference between traditional telephone and VoIP when there are 5% or 10% packet losses (In the developed world most VoIP is at 1% packet loss or less). Traditional telephone is better when there is severe packet loss (20%) |
| Lidestam, Danielsson, & Lonnborg (2006) | Telephone videos provided better comprehension than audio alone when the conversation partner provided visual contextual cues (e.g., pointing to watch to indicate time) |
| Maiorana-Basa & Pagliaro (2014) | Of 278 deaf and hard of hearing surveyed, 40-50% used video conferencing, 72% used smartphones, 71% used PCs |
| Ingrao (2013) | VoIP allows for the transmission of full spectrum of sound captured by the microphone, and often goes along with visual cues (i.e., Skype |
| Vanderheiden, 2006 | VoIP allows you to communicate through video, text AND speech |
| Ingrao (2014) | Google plus allows for audiovisual and text, zooms in on speakers mouth to facilitate lip reading, integrates documents to be collaborated on |
| Atcherson, Franklin, Smith-Olinde (2015) Chs. 10 and 7 | Facetime and skype allow for video calling. Dyssynchrony can exist between audio and visual cues, increasing transmission speed is decreasing this problem |

Supplement H

Findings Relating to Selecting Appropriate Coupling-Strategies

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| --- | --- |
| Author (year) | Finding or Recommendation |
| Lowe and Goldstein (1982) | No significant difference between acoustic and telecoil induction |
| Picou & Ricketts, (2011) | Unilateral wireless routing not better than acoustic |
| Kim et al. (2014) | Better intelligibility from bilateral wireless than from acoustic in both quiet and noise, as well as higher subjective ratings of quality, less noise, and more naturalness |
| Picou & Ricketts, (2013) | Unilateral telecoil induction and wireless better than acoustic for speech recognition and listening comfort; some participants did not position phone appropriately |
| Sorri et al. (2003) | Acoustic cell phone poorer than cell phone with telecoil induction loop |
| Julstrom, Kozma-Spytek, & Isabelle, (2011) | Half required 21 dB SNR (over induction noise floor) to consider acceptable for normal use |
| Smith & Davis (2014) | After being fit with wireless technology, participants experienced clearer signal, but phone did not pick up calls 100% of the time, there’s a limited battery life when using streamer, and frequently participants had to connect again with their cellphone each time they turned it on |
| Carol and Teixeira, (2014) | 47% report being unable to use telephone before hearing aids, only 12% 6 months after being fit |
| Stoker, French-St. George, & Lyons (1986) | Telecoil location did not make a significant difference to intelligibility, potentially because participants varied in how they positioned the telephone relative to the telecoil position (despite being told to position phone in such a way as to maximize signal level) |
| Holmes (1985) | No significant difference between coupling strategy (unaided, acoustic coupling with hearing aid, magnetic coupling with hearing aid) |
| Pyler, Burchfield, & Thelin (1998) | No difference between acoustic and magnetic in terms of intelligibility or background noise tolerance |
| Stoker (1981) | Speech intelligibility improved in the following order: acoustic, magnetic, telephone amplifier  High variability between individuals’ coupling preferences suggests the need to be respectful of individual differences |
| Stinson & Daigle (2004) | Feedback due to proximity of handset can reach 20 dB HL but by keeping handset 2 cm from pinna users can achieve almost the maximum possible reduction in feedback |
| Pichora-Fuller (1981) | Only 12% of participants reported benefitting from using their hearing aid on the telephone (5% used Telecoil, 7% used acoustic) |
| Ng, Phelan, Leonard, & Galster (2016) | Wireless connection with smartphones a good fit for heavy smart phone users and those looking to hear better over the phone, for example at work |
| Kepler, Terry, & Sweetman (1992) | 55% of hearing aid users keep them in when speaking on the phone, 10% report the coupling is problematic. Of those using telecoil induction (57%) about half report issues with interference from electric fields. Those using acoustic report discomfort in having to hold phone in odd position to avoid feedback. |
| Kaplan & Holmes (2010) | Removing hearing aid to use phone is the most common ‘coupling option’ followed by using the amplified phone, and then acoustically coupling phone to hearing aid, in last: telecoil induction with and without amplifier |
| Yoder & Pratt (2005) | Coupling issues frequently associated with accommodations (e.g., amplified phones don’t couple well with hearing aids) |
| Palmer (2001) | Need to turn hearing aids all the way up when using telecoil induction – telecoils need to be programmed to provide sufficient amplification |
| Martin (1983) | Telephones amplifiers can provide an output sufficient for up to a 70 dB HL loss. However, telecoil induction coupling is recommended because users can experience feedback if they use the amplifier with a hearing aid |

Supplement I

Findings Related to Mobile and Digital Phones

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| Author (year) | Finding or Recommendation |
| Ng, Phelan, leonard, & Galster (2016) | Linking the cell phone with hearing aids creates a more socially acceptable perception of hearing aids. Phone-hearing aid integration can convince some people to purchase hearing aids who otherwise wouldn’t. However, clients’ hopes for perfect hearing are generally not met. |
| Sorri et al. (2003) | Out of acoustic cell phone, telecoil induction cell phone, and landline, lowest intelligibility and subjective ratings found when cell phone was used acoustically; however, when cell phone was used with a telecoil induction loop it yielded similar results to those found with the landline |
| Federal Communication Commission (2016) | Federal communication commission requires that consumers with hearing loss have access to the voice technology options to which other consumers have access |
| Hearing Loss Association of America (2016) | The Federal Communication commission mandates that 85% of wireless phones be hearing aid compatibly by 2021 |
| Federal Communication Commission (2017) | Hearing aid compatible wireline phones must provide a sufficiently strong electromagnetic signal to allow for telecoil induction coupling, provide a volume range, and be labelled hearing aid compatible (HAC)  Hearing aid compatible wireless phones must have a T3 or T4 telecoil ratings and M3 or M4 RF emission ratings. Consumers must be able to try them before purchasing them at retail outlets  Hearing aids are also given M and T ratings to reflect their telecoil coupling strength and resistance to RF emissions. When adding the telephones ratings with the hearing aids rating, the sum should be 6 or higher to allow for the best listening conditions. |
| Federal Communication Commission (2018) | HAC compatible wirelines phones must be able to increase their volume by 12 dB at least |
| Vanderheiden (2006) | Smart phones allow for text messaging, text messaging while talking, and using video with voice. Can also be put on easy mode to make the phone very easy to operate |
| Hamlin (2012) | CDMA preferable to GMA, at least for iPhone 5. Need data and a phone plan to access captioned calls |
| Hamlin (2011) | Federal Communication Commission writes rules and regulations around communication. The Consumer Advisory Committee (CAC) which includes the Hearing Loss Association of America makes recommendation to the FCC |
| Atcherson, Franklin, Smith-Olinde (2015) Ch. 10 | Important that consumers try before they buy a mobile phone. They should experiment with the microphone, ask about hearing aid compatibility. Phonescoop.com allows users to search for relevant features (e.g., telecoil accessibility). Features of interest include vibrate mode, maximum volume, Bluetooth compatibility, video chat, senior mode (additional amplification in high frequencies) or text-only phones. Jitterbug is M4 T4 rated. Some American states can help with the purchase of compatible mobile phones through their telecommunication equipment distribution program.  \*\* DECT phones are Bluetooth enabled to transmit the signal directly to hearing aids. This presents less opportunities for interference (no conversion from electric to acoustic to electric to acoustic) and also eliminates the concerns about feedback. Not all hearing aids are currently compatible. Similar to the way that cell phones can be connected to some hearing aids. |
| Smith & Davis (2014) | After being fit with wireless technology, participants experienced clearer signal, but phone did not pick up calls 100% of the time, batteries drained more quickly, and frequently participants had to connect again with their cellphone each time they turned it on |
| Kozma-Spytek (2013) | Mobile phones can access captioning through an app that costs $75 for new users |

Supplement J

Findings Relating to Improving User’s Telephone Skills

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| --- | --- |
| Author (year) | Finding or Recommendation |
| Ferguson et al. (2015) | Online modules lead to significantly better telephone handling skills |
| Picou and Rickets (2013) | Participants do not consistently position phone optimally when using telecoil induction, even when reminded to do so |
| Campos, Bozza, & Ferrari (2014) | No significant difference between new and experienced hearing aid users in their practical hearing aid skills, lowest scores found for using telecoil induction |
| Wittich, Southall, & Johnson (2016) | Instruction and simple repetition led to significantly better skills in managing an amplified telephone (but could not bring lead everyone to use the amplified phone successfully) |
| Desjardins & Doherty, (2009) | Years of hearing aid use not linked with practical hearing aid skills, among all participants, telephone task (correctly using phone program, and positioning phone appropriately) was the lowest skill |
| Holmes, Kaplan, & Yanke (1998) | 26% report that they cannot use the phone with hearing aids |
| Iwahashi, Jardim, & Bento (2013) | At one-year follow-up 31.5% of new hearing aid users needed explanation of how to use the phone (most common form of counselling needed) |

Supplement K

Findings and Recommendations for Improving User’s Telephone Communication Tactics

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| --- | --- |
| Author (year) | Finding or Recommendation |
| Ferguson, Jongman, Sereno, & Keum, (2010) | Both over the telephone and face-to-face intelligibility scores decrease dramatically when the speaker is not a native English speaker. |
| Iezzoni, O’Day, Killeen, & Harker (2004) | In interviews with 12 clients who were hard of hearing and used hearing aids, participants recommended that:   * Health care providers review automated telephone menus and consider alternatives for persons with hearing loss * Providers ask about clients preferred communication approach; make appropriate effort to adhere to preferred approach * Periodically ask clients about effectiveness of communication; request suggestions to rectify unsatisfactory situations * periodically ask clients to summarize their understanding to identify miscommunications |
| Harris, Thomas, & Lamont (1981) | In interviews with 27 adults with moderately-severe to profound hearing loss it was found that these adults:   * Rely on family members and neighbors to manage phone calls * Do better if telephone communication partners don’t speak too quietly or shout and are willing to repeat/ rephrase * Are limited in the time they can spend on the phone by fatigue |
| Holmes, Kaplan, & Yanke (1998) | 26% of 19 participating veterans with hearing loss mentioned using communication strategies to improve phone calls in open-ended questionnaires |
| Scherich (1996) | Survey of 201 deaf and hard of hearing employees found that 56% reported having others handle their calls |
| Ingrao (2013) | Tips for making a call with a hearing loss:   * Prepare who you want to talk to, have their extension before hand * Disclose your hearing loss * Example: “Hello, I’m calling for Joe Smith, but want to tell you that I have a hearing loss and understand much better when people speak slowly and distinctly, spell names and repeat numbers twice. Thanks.” * Leave voice menus by saying ‘operator’ or ‘representative’ * Identify what works well in successful calls and try to replicate it |
| Caissie & Tranquilla (2010) | “What”, “pardon me”, or “huh” etc. don’t substantially help to fix communication breakdowns. Better to paraphrase and ask for clarification. Interrupting immediately after one misunderstands will allow the call partner to repeat the most relevant part. ‘Topic shading’ (i.e. moving to peripherally related topics in the conversation), increases miscommunications. It is important for conversation partners to indicate that they will be changing the topic with cues, such as a pause or a phrase (e.g. ‘by the way’). It may even be wise to confirm the new topic with the person before proceeding. Clear speech is characterized by fully saying each sound (as a result it is somewhat slower), while preserving the natural phrasing of speech. The focus on enunciating makes clear speech somewhat louder, but it not so much louder that it is distorted. People are best led to use clear speech by being instructed to "enunciate consonants more carefully and avoid slurring words together". The quality of clear speech improves with practice and conversation partners should be triggered to use it by the common nonspecific requests for repetition, such as “what?” |
| Castle (1994) | Workers can manage the phone by adopting strategies used by operators and airline agent, for example, spelling words using the NATO alphabet or breaking numbers into their single digit components. |

Supplement L

Findings and Recommendations for Requesting Accommodation for Telephone Work

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| Author | Finding or Recommendation |
| Ingrao (2014) | When requesting accommodation, the worker should change the narrative from “help me” to “help us”. They should learn more about what conditions are facilitators and barriers to their effective telephone communication and determine what works for them and what doesn’t. They should then use this information when making a request for accommodation and frame the request as a way to increase their productivity and the quality of customer service. They might ask for things such as an acoustically favorable office space, an amplified headset, a captioned phone (and training so others know how to use it).  If they can’t use the phone, they need to honestly admit that. They can offer to do other jobs, move to department that uses the phone less, or manage clients who prefer email, leaving phone work to colleagues.  Step by step, workers should:   * Identify what parts of their job are problematic * List job functions and the environment for each job function * Rate their ability to understand speech in each function and environment * Approach their manager with this as a clear argument for doing the tasks and working in the environment favorable to them. |
| Castle (1994) | When requesting accommodation, the worker with hearing loss needs to explain their preferred method of communicating, the cost, and how it will help them do their job. It may be advisable to bring in an assistive device one has purchased on their own for 30 days to demonstrate benefit to employer. It may be reasonable for employee and employer to share the cost. |
| Holmes (1994) | In the Unites States, there is a precedent of telephone amplifiers being considered a ‘reasonable’ workplace accommodation. |

Supplement M

Findings and Recommendations for Accounting for Individual Differences

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| Author | Finding or Recommendation |
| Garstecki (1994) | Before providing assistive devices, audiologists should consider:   * User’s capabilities and preferences * Situational needs (e.g., travelling or on the job) * Lifestyle considerations (communication demands, successes, failures) * Environment (noise, need for electrical outlets) * Independent management abilities * Costs of the device * Alerting needs (loud enough, acceptably unobtrusive, visual or vibro-tactile) |
| Kozelsky (2005) | People are ready for a telephone hearing solution when they:   * Have accepted their hearing loss * Are frustrated at not being able to hear well on the phone * Have a critical dependence on the telephone * Are lacking a high-power amplified phone * Are frustrated by the need to fumble, adjust and position the phone * Are benefitting from hearing aids during telephone use, * Have adequate manual dexterity   Providing a telephone demonstration centre can allow people to successfully try and adopt amplified phones |
|  |  |