**TABLE 1**: Descriptive summary of data extracted from the 41 included articles.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Study** | **num** | **Number of subjects** |  | **Mean age (years)** |  | **Type of hearing loss**  Mod.: moderate  Bilat.: bilateral  Mon.: monaural |  | **Stimuli** |  | **Configurations and processing** |  | **Method to measure listening effort** |  | **Test parameters**  A: HA vs. none  B: HA 1 vs. HA 2  C: NR; D: DIR; E: NAL; F: DSL; G: other |  | **Author hypothesis (HP)**  **1) LE: HI > NH**  **+: HP supported**  **-: HP not supported**  **=: no effect** |  | **Author hypothesis (HP)**  **2) LE: aided < unaided**  **+: HP supported**  **-: HP not supported**  **=: no effect** |
|  | **Subjective measures** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Ahlstrom et al. (2014) |  | a)n=14 NH  b)n=10 NH  c)n=12 HI |  | a)23.4  b)67.7  c)69.8 |  | c) Mild to mod. |  | consonant recognition (0° ,70 dB SPL) in SSN (0° or 90°, 66 dB SPL), stimuli  were low-pass filtered at fcut= 1.7, 3.4, 7.1 kHz |  | BTEs, bilateral, quasi-DSL v4.0 |  | VAS (0-15) |  | **A:** HA vs. none  **Hearing:** NH vs. HI |  | **1+)** LE unaided decreased with increasing bandwidth for group a, b and c  **Age effect:** LE: a < b for fcut = 1.7 and 3.4 kHz, no benefit of spatial separation |  | **2+)** group c: LE: aided < unaided only for spatially separated speech and noise at fcut = 1.7 kHz |
|  | Bentler & Duve (2000) |  | n=14 HI |  | 60.9 |  | Mild to mod. SHL |  | Real life (church and restaurant) recordings |  | 5 HAs tested:  **a)** linear HA, NAL-R  **b)** 1-channel compression HA, FIG6 prescription  **c)** digital HA**:** 2-channel WDRC, loudness fitting  **d)** digital HA |  | VAS (1-10) for all 5 HAs, random order |  | **B:** analogue vs. digital amplification  **B:** b) vs. c) vs. d) |  |  |  | **2=)** effect of HAs on LE in both real life conditions |
|  | Bentler et al., (2008) |  | n=25 HI |  | 65.1 |  | Mild to mod. bilateral SHL |  | AVETM created virtual sound environment of 3 personally problematic situations, 68-92 dBA |  | Bilateral BTE fitting: 4-channels, DNR, NAL-NL1 |  | VAS (1-10) effect of DNR |  | **B(C)** DNR-off vs. DNR-on (4, 8, 16s onset) |  |  |  | **2+)** LE rating: DNR-on < DNR-off, but no effect of DNR onset |
|  | Brons et al., (2013) |  | n=10 NH |  | 20.8 |  | <= 15 dB HL |  | sentences in multi-talker babble noise, SNRs -4, 0, + 4dB; HA output recordings presented via head phones |  | **B:** 4 DNR conditions from 4 HAs  **E**: NAL-RP |  | VAS (9-1),  1: no effort,  9: extreme effort  as #15 |  | **C:** DNR-off vs. DNR-on  **B(C):** NR1 to NR4 |  |  |  | **2=)** LE:DNR-on = DNR-off;  **2=)** LE: DNR1 and DNR4 < DNR2 and DNR3 |
|  | Brons et al., (2014) |  | n=20 HI |  | 61.3 |  | Mod. HL |  | Sentences in multi-talker babble, SRT 50% and fixed SNRs: -4, +4, +10 dB, monaural via head-phones |  | Hearing aid output recorded, with NAL-RP, for  a) DNR mild  b) DNR moderate  c) DNR strong  d) unprocessed |  | VAS (1-9) |  | **A:** processed vs. unprocessed  **B(C)**: a vs. b vs. c vs. d  **Stimulus:** -4 dB vs. +4 dB vs. +10 dB |  |  |  | **2-)** LE at fixed SNRs: c > a and d  **Stimuli**: -4 dB > +4 dB > +10 dB for a, b, c, d |
|  | Desjardins & Doherty (2013), \*see # 25) |  | a)n=15 YNH  b)n=15 ONH  c)n=16 OHI |  | a: 21.66,  b: 66.86,  c: 68.18 |  | a and b: <= 25 dB HL;  c: mild-mod., sensorineural HL |  | Sentences in ii) 1-talker babble, iii) 6-talker babble or iiii) SSN in free field, SNRs for 76% intelligibility |  | Only for c: personal HAs, bilateral, DSL, no DNR or DIR processing |  | VAS (100-0);  100: very easy,  0: very difficult |  | **Hearing**: a and b vs. c  **Age:** a vs. b and c  **Stimulus**: ii vs. iii vs. iiii |  | **1+)** LE: b < c for ii, iii and iiii  **1=)** LE: iiii < iii < ii: a = b = c |  |  |
|  | Desjardins & Doherty (2014), \*see # 26) |  | n=12 HI |  | 66.0 |  | Mild to mod., bilateral SHL |  | sentences in quiet and 2-talker babble for a) 50 % and b) 76% performance |  | bilateral BTEs:  DSL-v.5, DNR (such as #39) |  | VAS(100-0),  100: very easy,  0: very difficult |  | **B(F)**: DNR-on vs. DNR-off  **Stimulus:** a) vs. b) |  |  |  | **2=)** LE: DNR-on = DNR-off for a) and b)  **stimuli)** LE: b<a |
|  | Dwyer et al. (2014) |  | a)n=21 NH  b) n=30 UHI  c) n=20 UCI  d) n=16 UHA  e)c) and d) got CI🡪 CICI or CIHA |  | a)50  b) 50.5  c) 53.4  d) 60.3 |  | b, c, d): asymmetrical,  severe to profound HL |  | daily life environment 🡪 UCI, UHA, UHI, NH |  | Testing with own HAs/ CIs |  | SSQ (1-10) for e) pre- and post-CI (3 and 6 months) |  | **A:** NH (a) vs. HI (b, c, d)  **Group effects:** UHI, UCI, UHA  **Pre-vs. post CI:** UCI vs. CICI and UHA vs. CIHA |  | **1+)** LE: HI (b, c ,d) > NH |  | **2=)** LE: c = d  **2=)** c and d = b  **2=)** LE:post-CI = pre-CI  **2+)** LE: CICI and CIHA < b |
|  | Feuerstein (1992),  \*see # 28) |  | n=48 NH |  | 19 |  | ear plug: mon., conductive HL ~30 dB HL |  | Sound field: sentences (68°) in multi-talker background noise (68° and 65°), SNR: -5dB |  | a) monaural near (MN): good ear towards target  b) monaural far (MF) good ear toward masker  c) binaural listening (BIN) |  | Perceived LE: VAS (100-0) |  | **Stimuli:** c vs. a vs. b |  | **1+)** LE: c < a < b |  |  |
|  | Hällgren et al. (2005) |  | n=24 HI |  | G1:36.8 (n=12)  G2:71.8 (n=12) |  | mild-to-mod. SHL |  | Sentences in: a) quiet  b) modulated noise  c) competing talker  in two modalities:  i)auditory (loudspeaker)  ii) audio-visual ( loudspeaker+ visual cues) |  | Own bilateral HAs |  | VAS (0-10) |  | **A:** HA vs. none  **Background:** a vs.. b vs.. c |  |  |  | **2+)** LE: aided < unaided  Greater HA benefit in a) than in b) and c);  **LE(background):** c > b> a |
|  | Harlander et al. (2012) |  | n=14 HI |  | 66 |  | Asymmetrical, mod. SHL |  | Sentences in: a)multi-talker babble, b)street noise, c)printer noise  d)quasi-stationary noise  SNRs: -5 to 15 dB, in 4dB- steps |  | MHA, 3 DNR systems:  i)CBB  ii) AMS  iii) MS |  | VAS (1-13) |  | **B(C):** unprocessed vs. i vs. ii vs. iii  **Stimuli:** a vs. b vs. c vs. d for all SNRs |  |  |  | **2-)** LE: unprocessed < iii especially for c and d  **2+)** LE: unprocessed > ii only for b  **2+)** LE: unprocessed > i for a, b, c;  LE: iii > ii > i  Stimuli: positive (better) SNRs reduced LE |
|  | Hicks & Tharpe (2002), \*see # 31) and # 46), **only exp. 2** |  | n=14 HI  n=14 NH |  | NH and HI: 8.8 |  | mild to mod. SHL |  | a) words (PBK) in quiet  b) speech babble: +20, +15, +10 dB SNRs |  | Own HAs during testing  N=12: own HA binaural  N=1: HA monaural  N=1: no HA |  | VAS (1-5) |  |  |  | **1=)** NH = HI |  |  |
|  | Hornsby (2013),  \*see # 32) |  | n=16 HI |  | 65.8 |  | Mild-severe SHL |  | Words, 70% intelligibility ( 0°) in cafeteria babble noise from 60°, 120°, 180° , 240° |  | Multi-channel HAs: a) OMNI and feedback management; b) DIR, DNR, wind noise and reverberation reduction, |  | pre-DTP and post-DTP LE ratings;  SSQ (0-10) questions # 14, # 18, # 19 |  | **A:** HA vs. none |  |  |  | **2=)** LE: unaided = aided (for a and b);  LE: pre-DTP < post-DTP |
|  | Humes et al. (1997) |  | a) n=41 HI  b) n=53 HI  c) n=16 HI |  | Age range  a) 27-85  b) 34-87  c) 47-90 |  | Symmetrical  a) mild SHL  b) mod. SHL  c) severe SHL |  | sentence recognition in quiet, multi-talker babble and cafeteria noise, free field, +5, +10 dB SNRs |  | binaural HA fitting, NAL-R |  | VAS (100-0),  100: extremely easy,  0: very difficult |  | **A:** HA vs. none  **B:** BILL vs. linear |  | **1+)** LE interaction: HL x noise x HA setting: c > a for BILL in babble noise |  | **2=)** LE: BILL = linear |
|  | Humes et al. (1999) |  | n=55 HI |  | Not given |  | Symmetrical, mild- severe HL |  | sentence recognition in quiet (50, 60, 75 dB SPL) and babble noise at +5, +10 dB SNR |  | 2 binaural sets of ITC-HAs  HA1: BILL with NAL-R  HA2: 2-channel WDRC, DSL[i/o] |  | VAS (0-100) |  | **A:** HA vs. none  **B**: HA1 vs. HA2 |  |  |  | **2+)** LE: unaided > HA1 > HA2 for n=55 in quiet (50 and 60 dB SPL) |
|  | Luts et al. (2010) |  | n=38 NH  n=34 HI-F  n=37 HI-S  (F: flat, S: steep slope) |  | NH: 30  HIF: 62  HIS: 68 |  | NH: <= 20 dB HL  HI: mod. SHL |  | Sentences (0° azimuth) in background noise (90°, 180°, 270°), in office like room; SNRs: -10, -5, 0, +5, +10 dB |  | Binaural MHA fitting, NAL-RP; |  | VAS (0-6),  0: no effort,  6: extreme effort |  | **B1:** unprocessed vs. processed  **B2:** SC1, SC2, BSS, WMF, COH  **Hearing:** NH vs. HI  **Stimulus:** 5 SNRs |  | **1+)** LE: HI > NH |  | **2+)** LE:MWT < unprocessed, largest effect at -10,-5, 0 dB SNRs  **2+)** LE: SCI, SC2, COH < unprocessed at 0 dB SNR only  **2-)** LE: BSS > unprocessed for all SNRs |
|  | Mackersie et al. (2009) |  | n=14 HI |  | 76 |  | mild to mod. bilateral SHL |  | Sentences (75 dB SPL) in speech babble, +5dB SNR, free field |  | Simulated cellular phone encoding: wide and narrow band;  HA functions: multi-channel, DIR, feedback cancellation, NAL-NL1 |  | VAS (9-1) |  | **Stimulus:** quiet vs. noise  **B1:** wide-band vs. narrow band encoding  **B2:** individualized-amplification vs. standard setting |  |  |  | **Stimuli:** LE: quiet < noise  **2+)** LE**:** individual amplification < standard setting  **2=)** LE: wide band = narrow band encoding |
|  | Neher et al. (2014),  \*see # 36) |  | n=10:GH+C+,  n=10: GH-C+,  n=10: GH+C-,  n=10: GH-C-  H: hearing  C: cognition  +:good, -: poor |  | GH+C+: 73  GH-C+: 75  GH+C-: 76,6  GH-C-: 75.5 |  | bilateral SHL |  | Sentences in cafeteria noise, at -4, 0, +4 dB SNR |  | MHA:NAL-RP; OFF: NR inactive; ON: active NR;  ON+g: active NR with restored stimuli long term spectrum  Noise (N) or speech (S) processing |  | VAS(1-9) |  | **B:** SoffNoff, SonNon, Son+gNon+g, SoffNon+g, Son+gNoff  **Stimulus:**  -4 vs. 0 vs. +4 dB SNR  **Group** **effect**:  H+ vs. H- and C+ vs. C- |  |  |  | **2+)** LE: SonNon < Son+gNoff andSoffNoff  **2+)** LE:SonNon and SoffNon+g < SoffNoff andSon+gNoff at 0dB and +4dB SNR  **2+)** LE (interaction: processing condition x group): SonNon < SoffNoff for all groups but smallest benefit for GH-C- compared to other groups  **2=)** LE: at -4 dB SNR similar across processing conditions  **Stimuli**: LE: -4 dB > 0 dB > +4 dB |
|  | Noble & Gatehouse (2006) |  | n=144: no HA  n=118: 1 HA  n=42: 2 HAs |  | no HA: 68.3  1 HA: 66.2  2 HAs: 66.4 |  | Mild to mod. SHL |  | Rating of listening in everyday world, conversations |  | HA fitting:  volume control, NAL-RP |  | SSQ (1-10) |  | **A**: no HA vs. 1 HA vs. 2 HAs |  |  |  | **2+)** LE: 2HA < 1HA < no HA |
|  | Noble et al. (2008) |  | n=36: CICI  n=70 CI  n=39 CIHA |  | CICI: 64.8  CI: 60.7  CIHA: 61.4 |  | severe SHL |  | Rating of daily listening situations |  | Participants own CI or HA |  | SSQ-50 |  | **B:**CI vs. CICI vs. CIHA  **A:** pre vs. post implantation |  |  |  | **2+)** LE: CICI< CI < CIHA  **2+)** LE: pre implant > post-implant for CI and CICI but not for CIHA |
|  | Palmer et al. (2006) |  | 49 HI |  | 62.1 |  | Mild-mod. SHL |  | daily listening environment |  | BTEs fitted: NAL-NL1, DNR, adaptive feedback management; P1: fixed OMNI; P2: adaptive DIR  P3: fixed DIR, P4: telecoil |  | VAS (completely agree - disagree) and diary on HA use |  | **B:** P1 vs. P2 vs. P3 |  |  |  | **2=)** tiredness: P1 = P2 = P3 |
|  | Pals et al. (2013),  \*see # 37) |  | 19 NH |  | 22 |  | < 20dB HL |  | noise-vocoded sentences |  | Noise vocoding for 2, 4, 6, 8, 12, 16, 24 channels |  | VAS(0-100) |  | **B:** unprocessed vs. vocoded speech (all channels)  **Stimulus**: single task vs. dual tasks (judgment, mental-rotation) see 35) |  |  |  | **2+)** decreased LE for # channels < 6 compared to unprocessed speech;  LE: both dual-tasks > single task |
|  | Rudner et al. (2012)  **only exp. 2** |  | 30 HI |  | 70 |  | Mild to mod. SHL |  | sentences in SSN and modulated noise at -2, +4, +10 dB SNR |  | Participant’s own BTEs |  | VAS(no effort to maximum possible effort) |  | **B**: fast vs. slow compression as between subject factor |  |  |  | **2=)** no main effect of compression on effort |
|  | Zekveld et al. (2011), \*see # 51) |  | n=28 NH  n=36 HI  n=38 YNH from 2010 |  | NH: 55  HI: 61  NHY: 23 |  | NH and YNH: <+20 dB HL  HI: mild-mod. HL |  | Sentences in stationary noise, in free field, a)in quiet, b)50% intelligibility, c) 71%, d) 84% |  | Internal processing HI vs. NH |  | VAS(0-10),  0: no effort,  10: high effort |  | **Hearing:** NH vs. HI  **Stimulus:** SRT50% vs. SRT71% vs. SRT84%  **Age:** 23 vs. 55,61 years |  | Stimuli: LE: b > c > d  **1=)** LE: HI = NH |  |  |
|  | ***Behavioral measures*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Desjardins & Doherty (2013), \*see # 6) |  | a)n=15 YNH  b)n=15 ONH  c)n=16 OHI |  | a: 21.66,  b: 66.86,  c: 68.18 |  | a and b: <= 25 dB HL;  c: mild-mod., sensorineural HL |  | Sentences: high and low context in i) quiet (70dB SPL) or ii) 1-talker babble, iii) 6-talker babble or iiii) SSN in free field, SNRs for 76% intelligibility |  | See # 5) |  | DTP: Task 1: sentence recall  Task 2: visual motor tracking |  | **hearing**: a and b vs. c  **age**: a vs. b and c  **Stimulus**: i vs. ii vs. iii vs. iiii  **Stimulus:** high vs low context |  | LE: YNH: iii> iiii  **1+)** LE: b and c > a in ii and iiii  **1=)** LE: b = c, in all masker conditions  **1=)** LE: high = low context across ii, iii and iiii for a, b and c |  |  |
|  | Desjardins & Doherty (2014), \*see # 7) |  | n=12 HI |  | 66.0 |  | Mild to mod., bilateral SHL |  | sentences in quiet and 2-talker babble for a) 50 % and b) 76% performance |  | bilateral BTEs:  DSL-v.5, DNR (such as #39) |  | DTP: Task 1: sentence recall  Task 2: visual motor tracking |  | **B(C)**: DNR-on vs. DNR-off  **Stimulus:** a) 50% vs. b) 76% performance |  |  |  | **2+)** LE: DNR-on < DNR-off for b  **2=)** LE: DNR-off = DNR-on for a  **2+)** LE: b > a for DNR-off  but LE: a = b when DNR-on |
|  | Downs (1982) |  | n=23 HI |  | 51 |  | N=16 bilat. SHL  N=1 bilat. mixed  N=6 mon. SHL, mon. mixed HL |  | CNC words in multi-talker babble, 0dB SNR, free field |  | Individual BTE fitting:  -n=10: 3 fittings tested  -n=12: 2 fittings tested  -n=1: 1 fitting tested |  | DTP: task 1: word recall  Task 2: ViRT |  | **A:** HA vs. none |  |  |  | **2+)** ViRTs: with HA < without HA |
|  | Feuerstein (1992),  \*see # 9) |  | n=48 NH |  | 19 |  | ear plug: mon., conductive HL ~30 dB HL |  | SPIN sentences and light flash |  | a) monaural near (MN): good ear towards target  b) monaural far (MF) good ear toward masker  c) binaural listening (BIN) |  | attentional LE: DTP  task 1: sentence recall  task 2: ViRT |  | **Hearing:** c) vs. a) and b)  a(MN) vs. b(MF) |  | **1=)** LE: c = a  **1+)** LE: c < b and a < b  Attentional LE not correlated with perceived LE (see #7) |  |  |
|  | Gatehouse & Gordon (1990) |  | n=44 HI |  | 68 |  | Symmetric, mild- mod. SHL |  | a) Tones: 60, 80 dB SPL  b) SSN: 60, 70, 80 dB SPL  c)words: 60, 70, 80dB SPL  d) sentences, levels as c)  c) and d) in quiet and +5 dB SNR with b); free field |  | HA fitted |  | RT for response to all stimulus |  | **A:** HA vs. none  **Stimulus:** 60 vs. 70 vs. 80 dB SPL |  |  |  | **2+)** RT: aided < unaided, effect larger for d) than c);  **Stimuli:** RT: 60 < 70 < 80 dB SPL for a) |
|  | Gustafson et al. (2014) |  | n=24 NH |  | Age range: 7-12 |  | thresholds <= 15 dB HL |  | CVC non-words in broadband noise; 60 and 65 dBSPL; SNRs: +5dB, 0dB, recorded HA output monaurally presented via headphones |  | 2 different HAs fitted : DSL v5.0, amplitude modulation detection |  | Verbal RTs for non-word repetition |  | **B:** DNR-on vs. DNR-off  **Stimulus:** 0dB vs. +5dB SNR  **Hearing:** HA1 vs. HA2 |  |  |  | **2+)** RTs: DNR-on < DNR-off, no variation across both HAs;  **Stimuli:** RTs**:** +5 dB < 0 dB SNR |
|  | Hicks & Tharpe (2002),  \*see #12) and #46), **only exp. 2** |  | n=14 HI  n=14 NH |  | NH and HI: 8.8 |  | mild to mod. SHL |  | a) words (PBK) in quiet  b) speech babble: +20, +15, +10 dB SNRs |  | Own HAs during testing  N=12: own HA binaural  N=1: HA monaural  N=1: no HA |  | DTP: Task 1: word recall  Task 2: ViRT |  | **Hearing:** NH vs. HI  **Stimulus:** a vs. b |  | **1=)** baseline RTs: NH = HI  **1+**) ViRT: HI > NH in all conditions |  |  |
|  | Hornsby (2013), \*see # 13) |  | n=16 HI |  | 65.8 |  | Mild-severe SHL |  | Words, 70% intelligibility ( 0°) in cafeteria babble noise from 60°, 120°, 180° , 240° |  | Multi-channel HAs: a) OMNI and feedback management; b) DIR, DNR, wind noise and reverberation reduction, |  | DTP: Task 1: word recall  Task 2: memory recall and ViRTs |  | **A:** HA vs. none  **B:** a vs. b |  |  |  | **2+)** RT: unaided > b  **2=)** RT: unaided = a |
|  | Kulkarni et al. (2012) |  | Exp.1:  n=6 NH  Exp.2.  n= 8 HI |  | Exp.1: 35-45  Exp.2: 32-66 |  | Exp.1:  thresholds <20dB HL  Exp.2:  Mod.-severe SHL |  | Exp. 1 only NH:  CVC recognition in broad band noise; SNR: 6, 3, 0, -3, -6, -12, -15 dB  Exp. 2: only HI:  CVC recognition in quiet  Exp 1 and 2: monaural testing via headphones; |  | Exp.1 and 2  Multi-band frequency compression, CRs: uncompressed, 0.8, 0.6, 0.4, applied on speech |  | Exp. 1 and 2: RT for stimulus |  | Exp. 1 and 2  **B:** uncompressed vs. compressed speech (all CRs)  **Stimulus:** Range of SNRs |  |  |  | Exp.1:  **2+)**RTs for uncompressed: (SNR<0dB)>(SNR>0dB) **but** RT(all CRs):  (SNR <0dB) < (SNR >0dB);  Exp1: **stimuli:** increased RTs for decreasing SNRs  Exp.2: **2+) RTs:**  compressed<uncompressed |
|  | Martin & Stapells (2005)  \*see # 49) |  | n=10 NH |  | 33 |  | <=20 dB HL |  | Deviant stimuli: /ba/, /da/, monaural, at i) 65 and ii) 80 dB ppSPL in  a)quiet  b)low pass filtered noise, fc = 250, 500, 1k, 2k, 4kHz, at 50% masking threshold, ipsilateral |  | HL simulation by masking noise |  | RTs during discrimination of deviant stimuli |  | **Noise:** fc effect  **Stimulus:** a) vs. b) |  | **1+)** RTs: 65 dB > 80 dB ppSPL  **1+)** RT: (fc<1kHz) > (fc>1Hz) only for i)  **1+)** RTs: a) < b) for all fc but especially with increasing fc |  |  |
|  | Neher et al. (2013) |  | GH+C+=10 NH  GH-C+-=10 HI  GH+C-=10 NH  GH-C-=10 HI  H+/- NH / HI  C+/- cognition good / poor |  | GH+C+=72.1  GH-C+-=74.7  GH+C-=75.8  GH-C-=75.0 |  | GH+C+,PTA: 36.4  GH-C+-,PTA: 53.7  GH+C-,PTA: 38.1  GH-C-,PTA: 57.1 |  | Sentences (convolved with head-related impulse responses from cafeteria babble) in quiet and SNRs: -4, 0, 4 dB |  | MHA with NAL-RP  a) DNRoff  b) DNRmoderate  c) DNRstrong |  | DTP (see # 39) )  Task 1: sentence recall  Task 2: ViRTs |  | **B:** a) vs. b) vs. c)  **Stimulus:**  -4 vs. 0 vs. +4 dB SNR  **Hearing:** HI vs. NH |  |  |  | **2-)** ViRT: DNRstrong > DNRmoderate and DNRoff for all groups  **Stimuli:** LE: reduced ViRTs with increasing SNR |
|  | Neher et al. (2014)  \*see # 18) |  | n=10:GH+C+,  n=10: GH-C+,  n=10: GH+C-,  n=10: GH-C-  H: hearing  C: cognition  +:good, -: poor |  | GH+C+: 73  GH-C+: 75  GH+C-: 76,6  GH-C-: 75.5 |  | bilateral SHL |  | Sentences in cafeteria noise at 0 and -4dB SNR |  | MHA:NAL-RP; OFF: NR inactive; ON: active NR;  ON+g: active NR with restored stimuli long term spectrum  Noise (N) or speech (S) processing |  | DTP: task 1: sentence recall  Task 2: ViRT |  | **B:** SoffNoff, SonNon, Son+gNon+g, SoffNon+g, Son+gNoff  **Stimuli** -4 vs. 0 dB SNR  **Group** **effect**:  H+ vs. H- and C+ vs. C- |  | Stimuli:  -4 dB SNR > 0dB SNR  **1=)** ViRT: no group effect |  | **2-)** ViRT: SoffNoff and all other conditions < SonNon  **2+)** ViRT: SonNon > Son+gNon+g, |
|  | Pals et al. (2013)  \*see # 22) |  | n=19 NH |  | 22 |  | < 20dB HL |  | noise-vocoded sentences |  | Noise vocoding for 2, 4, 6, 8, 12, 16, 24 channels |  | DTP: task 1: sentence recall  task 2: rhyme judgment and mental rotation |  | **B:** unprocessed vs. vocoded speech (2 to 24 channels) |  |  |  | **2+)** ViRT: (2-8 channels) > (9-24 channels) |
|  | Picou et al. (2013) |  | n=27 HI |  | 65.3 |  | Bilateral, SHL |  | Words (65dBA) in quiet and 4-talker babble, 50% to 70% performance, AO and AV cues |  | bilateral HA fitting: NAL-NL1, digital feedback suppression |  | DTP: task 1: word recall  task 2: ViRT |  | **A1:** HA vs. none  **Stimulus1:** words in quiet vs. babble noise  **Stimulus2**: AO vs. AV |  |  |  | **2+)** ViRT: HA < no HA  ViRT: AO = AV and no interaction with HA use or noise  ViRT: quiet < noise |
|  | Picou et al. (2014) |  | n=18 HI |  | 69.1 |  | Mild to mod. SHL |  | Monosyllable words (62 dBA), in background noise (55dBA), audio-visual presentation |  | bilateral BTEs: NAL-NL1, feedback reduction  DIR: a) mild, b) moderate, c) strong; DNR active only for b) and c) |  | DTP (as 35))  task 1: word recall  task 2: ViRT |  | **B(D):** a vs. b vs. c  **C:** DNR inactive for a vs. active b and c |  |  |  | **2=)** ViRT: DIR-off = DIR-on  for n=17 |
|  | Rakerd et al. (1996) |  | Exp. 1  n=8 NH,  n=9 HI  Exp. 2:  n=11 NH,  n=11 HI |  | Exp.1:not given, young  Exp.2: NH: 24; HI2: 62 |  | Exp. 1:  NH: < 15 dB HL;  HI: congenital /early onset HL  Exp.2: HL through presbyacusis |  | Exp.1 and 2:  a)speech  b) SSN |  | Exp. 1 and 2: monaural testing via headphones  NH: speech at 65dB SPL  HI: amplification for MCL |  | Exp. 1 and 2: DTP  Task 1: listening to a) or b) with following questions for a)  Task 2: digit memorization (9 digits for exp.1, 11 for exp.2 |  | Exp. 1 and 2:  **Hearing:** NH vs. HI  **Stimulus:** a) vs. b) |  | Exp.1 and 2:  **1+)** recall: HI < NH  Exp1 and 2: recall: a < b  **1+)** forgotten digits:  HI (exp1) > HI (exp2) > NH |  |  |
|  | Sarampalis et al. (2009)  **only exp. 2** |  | n=25 NH |  | 21 |  | <= 15 dB HL |  | sentences in  a)quiet, 65 dB SPL  b)4-speaker babble, SNRs: -6, -2, +2dB, headphone presentation |  | i)unprocessed  ii) DNR only for b) |  | DTP: task 1: sentence recall  Task 2:ViRT |  | **Stimulus:** a) vs. b)  **B(C):** i) vs. ii) |  |  |  | **2=)** ViRTs: i) = ii) for SNRs: -2, +2dB  **2+)** ViRTs: i) > ii) for SNR: -6dB only;  ViRTs: a) < b) for all SNRs |
|  | Stelmachowicz et al. (2007) |  | n=32 NH  n=24 HI |  | Range: 7-14  n=14 in 4 age groups |  | NH: < 20dB HL  HI: Mild to severe SHL |  | b) PBK words in SSN, SNR:+8 dB, bandwidth (BW): a)stimuli filtered at 5kHz, b) filtered at 10kHz |  | HI: DSL (v.5.0) |  | DTP: task 1: word recall  Task 2: digit recall |  | **Stimulus**:5 vs. 10 kHz BW  **Hearing:** NH vs. HI  **Age:** 7-8 vs. 9-10 vs. 11-12 vs. 13-14  **Tasks:** dual vs. single |  | Stimuli: single-task < dual-task for HI and NH, for a) and b)  **1=)** LE (digit recall): a) = b) for NH and HI  Age: 9-10 HI < all other; 13-14 NH < all other |  |  |
|  | Tun et al., 2009 |  | n=12: ONH  n=12: OHI  n=12: YNH  n=12: YHI |  | YNH and YHI: 27.9;  ONH and OHI: 73.9 |  | Sensorineural, mild- mod. HL |  | Words: related and unrelated;  insert ear phone, monaural at better ear, 70 dB HL |  | Internal processing HI vs. NH |  | DTP: task 1: word recall  Task 2: mean % time on target for visual tracking |  | **Hearing**: NH vs. HI  **Age**: young vs. old |  | **1+)** LE: OHI > ONH  **1=)** LE: YHI = YNH |  |  |
|  | Wu et al. (2014) |  | Exp.1:  n=29 HI  Exp. 2:  n=19 HI  Exp.3:  n=24 NH |  | Exp.1: 72.7  Exp. 2: 72.7  Exp. 3: 23.4 |  | Exp. 1 and 2:  SHL  Exp. 3:  <=25 dB HL |  | Exp. 1, 2, 3:  Sentences in road-noise, -1 dB SNR; |  | Exp. 1 and 2:  Recordings of HA output: compression, feedback suppression, NAL-NL1, DNR-off, stimuli presentation: ear-phones  Exp. 3:  MCL for directional conditions, no HL dependent amplification |  | Exp. 1: DTP  Task 1: sentence recall  Task 2: driving vehicle in simulator  Exp. 2 and 3: DTP: Task 1: sentence recall  Task 2: ViRT |  | Exp 1, 2:  **A:** HA vs. none  **B:** OMNI vs. DIR  **Stimulus:**  single-task vs. dual-task  Exp. 3:  **A:** unaided vs. aided  **B:** OMNI vs. DIR |  | Exp. 1:  Speech perception:  dual-task < single-task  Exp. 2:  Speech perception:  dual-task = single-task  Exp. 3:  **1+)** LE: young NH < elderly HI |  | Exp. 1:  **2=)** no effect of HA conditions on driving performance  Exp 2:  **2=)** no effect of HA conditions on RTs  Exp. 3:  **2+)** RT: DIR < OMNI  **2+)** RT: DIR < unaided |
|  | ***Physiological measures*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Kramer et al., 1997 | 14 | n=14 NH  n=14 HI |  | NH: 29  HI: 44 |  | HI: mild- mod. |  | Sentences in fluctuating noise at: a) SRT, b) SRT+5, c) SRT+10, d) noise only |  | Internal processing HI vs. NH |  | Pupil during listening: i) peak amplitude, ii) mean dilation, |  | **Hearing:** NH vs. HI  **Stimulus:** a vs. b vs. c vs. d |  | Stimulus: i: a > b for HI and NH  **1+)** ii: HI < NH between a vs. b |  |  |
|  | Hicks & Tharpe (2002) \*see # 12) and # 31), **only exp. 1** |  | n=10 HI  n=10 NH |  | HI: 8.1  NH: 7.11 |  | mild-to-mod. SHL |  | Classroom environment |  | Own HAs during testing  n=8: binaural HAs  n=1: monaural HA  n=1: no HA |  | Saliva samples (beginning and end of school day, 2 days) for cortisol concentration |  | **Hearing:** NH vs. HI |  | **1+)** cortisol levels: HI > NH for morning and afternoon samples |  |  |
|  | Oates et al., 2002 |  | n=20 NH,  n=20 HI |  | NH: 30.3,  HI: 31.2 |  | NH <= 15 dB HL,  HI: PTA1: 0-24 dB,  PTA2: 25-49 dB,  PTA3: 50-74 dB,  PTA4: 75-120 dB |  | /ba and /da at  i) 65dB ppe SPL  ii) 80 dB ppe SPL  via sound field |  | Internal processing HI vs. NH |  | EEG: N2 and P3: a) amplitude, b) latency, RT to deviant stimuli |  | **Hearing:** NH vs. HI  **Stimulus:** i) vs. ii) |  | **1+)** b (N2,P3): PTA1 and PTA2 > NH for i  **1=)** a(N2,P3): PTA1 and PTA2 = NH for i  **1+)** a(N2,P3): PTA3 and PTA4 < NH for i and ii  **1+)** b (N2,P3): PTA3 > NH for ii  **1-)** a (P3): PTA3 > NH for ii |  |  |
|  | Korczak et al. (2005) |  | n=20 NH  n=14 HI |  | 30.3  29.3 |  | NH: <= 15 dB HL  HI: mild-severe HL |  | /ba and /da at  i) 65dB ppe SPL  ii) 80 dB ppe SPL  via sound field |  | Only for HI: a) unaided  b) personal HAs |  | EEG: N2 and P3 and RTs to stimuli |  | **A:** HA vs. no HA  **Stimulus:** i) vs. ii) |  | **1+)** P3 and RT latencies for i): HI > NH |  | **2+)** detectability of N2, P3,  aided > unaided, for HI in i) |
|  | Martin & Stapells (2005)  \*see # 34) |  | n=10 NH |  | 33 |  | <=20 dB HL |  | /ba/, /da/, monaural,  at i) 65 and ii) 80 dB ppe SPL in a)quiet  b)low pass filtered noise, fc = 250, 500, 1k, 2k, 4kHz, at 50% masking threshold, ipsilateral |  | HL simulation by masking noise |  | EEG measures for  a) RT for deviant stimuli perception  b)ignoring deviant stimuli while reading  i)N1: speech audibility  ii)P3: stimulus discrimination |  | **Stimulus:** fc effect  **Stimulus:** quiet vs. noise |  | **1+)** N1 amplitude decreases when fc increases only for i)  **1+)** N1 latency:  (fc<1kHz) >(fc>1kHz)  **1+)** P3 only present for fc <4kHz  **1+)** P3 amplitude: (fc<1kHz) > (fc>2kHz)  **1+)** P3 latency: (fc<1kHz) > (fc>1kHz) |  |  |
|  | Wild et al. (2012) |  | n=21 NH |  | 21 |  | Self-report of NH |  | 3 attentional conditions: a) sentences  b) auditory distracter  c) visual distracter  4 intelligibility conditions  i) clear speech  ii) 6-band NV  iii)compressed 6-band NV  iiii) spectrally rotated NV |  | noise vocoding |  | fMRI while decision making for a, b or c by key press |  | **Stimulus**: a vs. b vs. c  **Stimulus**: i, ii, iii, iiii |  | **1+)** attentional task: LE: i < ii and iii |  |  |
|  | Zekveld et al. (2011),  \*see # 24) |  | n=28 NH  n=36 HI  n=38 YNH  from 2010 |  | NH: 55  HI: 61  NHY: 23 |  | NH and YNH: <+20 dB HL  HI: mild-mod. HL |  | Sentences in stationary noise, in free field, a)in quiet, b)50% intelligibility, c) 71%, d) 84% |  | Internal processing HI vs. NH |  | Pupil during listening:  i) peak amplitude,  ii) mean dilation,  iii) peak latency,  iiii) response duration |  | **Hearing:** NH vs. HI  **Stimulus**:SRT50% vs. SRT71% vs. SRT84%  **Age:** 23 vs. 55,61 years |  | **1+)** decline with increasing SNR in i), ii): HI < NH, less strong for NHY  Age: iiii): NHY < NH, HI and baseline ii): NHY > NH, HI |  |  |

Extended data for 41 articles arranged by subjective, behavioral or physiological measurement types in alphabetical order. Articles describing studies using multiple types of measurement appear in multiple rows.

**vs.:** versus; **NH:** normal hearing**, HI:** hearing-impaired, **UHI:** unilateral HI; **(S)HL:** (sensorieneural) hearing loss, **CI:** Cochlear Implant; **UCI:** unilateral CI; **PTA**: pure tone average**; MCL:** most comfortable level; **HA:** hearing aid; **UHA:** unilateral HA; **VRT**: verbal response time; **DNR:** digital noise reduction; **NR:** noise reduction; **HA:** hearing aid**; BTE:** behind-the-ear HA; **ITC:** in the channel HA; **OMNI**: omnidirectional; **DIR:** directional; **ViRT:** visual response/reaction time; **RT:** reaction time; **SRT:** speech recognition test, **LE:** listening effort; **PR:** preference ratings; **Exp.:** experiment; **SSN**: speech-shaped noise; **ppeSPL**: peak-to-peak equivalent SPL; **DTP:** dual-task paradigm; **S+N:** speech + noise; **AO:** auditory only; **AV:** auditory visual; **SSQ:** Speech Spatial and Qualities of hearing scale SSQ (Gatehouse & Noble, 2004); **NAL:** [National Acoustic Laboratories](http://www.nal.gov.au/nal-software_tab_nal-nl-1.shtml) prescription (Byrne & Dillon, 1986), **CVC:** revised consonant-vowel-consonant words (Peterson and Lehiste, 1962); **CBB:** Codebook-Based (Rosenkranz, 2010), **AMS:** Amplitude Modulation System-Based (Tchorz & Kollmeier, 2003), **MS:** minimum statistics (Martin et al., 2004); **MHA:** Master Hearing Aid research platform (Grimm et al. 2006);