A systematic narrative synthesis of acute amplification-induced improvements in cognitive ability in hearing-impaired adults

Sridhar Kalluri¹, Brianne Ahmann¹ and Kevin J. Munro²,³

¹Starkey Hearing Research Center, Berkeley, CA, USA; ²Manchester Centre for Audiology and Deafness, School of Health Sciences, University of Manchester, Manchester, UK; ³Manchester Academic Health Science Centre, Manchester University Hospitals, NHS Foundation Trust, Manchester, UK

ABSTRACT

Objective: This systematic review investigated if hearing aid use was associated with acute improvements in cognitive function in hearing-impaired adults.

Design: The review question and inclusion/exclusion criteria were designed using the Population, Intervention, Control, Outcomes, and Study design (PICOS) mnemonic. The review was pre-registered in the International Prospective Register of Systematic Review (PROSPERO) and performed in accordance with the statement on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Study sample: Thirteen articles, of various designs, published between 1990 and 2018, were identified via a search of five electronic databases.

Results: Most studies reported 1–2 cognitive outcome measures. Nine studies reported a significant improvement in outcome and four studies reported no significant change. None of the 13 studies received a high score on a quality assessment checklist. Due to concerns over risk of bias and indirectness, the overall quality of evidence was graded as low.

Conclusions: Only a few studies were identified, some of which report a small improvement in cognitive outcome; however, the overall quality of evidence was low. Further research is very likely to have an important impact on our confidence in answering the review question.

Introduction

It is well documented that successful listening requires effective cognitive processing, especially in circumstances that degrade the auditory input (Akeroyd 2008; Peelle 2017) or when listening goals are complex (Neher et al. 2011; Woods et al. 2013; Xia et al. 2017). On the other hand, less established is that successful hearing leads to improvement in cognition. The aim of this systematic review was to investigate if amplification by hearing aids leads to acute (i.e. rapid) improvements in cognitive function in adults.

There are several explanations for why hearing-aid use may acutely improve performance on a cognitive test. First, by improving access to auditory information, hearing aids may reduce the cognitive resources consumed by listening and thereby lead to improved performance on a concurrent cognitively demanding task (Sarampalis et al. 2009). Such concurrent task measurements are useful adjuncts to conventional measures of hearing-aid outcome, even if they are not necessarily indicative of improved cognitive ability. Second, the neural circuitry mediating a cognitive function can be strengthened and refined through repeated use (Merzenich, Van Vleet, and Nahum 2014). Hearing aids may promote such neural plasticity because an enriched auditory input enables the greater exercise of cognitive skills involved in listening (e.g. more audible sound sources may call for greater engagement of the neural mechanisms of selective attention). Finally, generalised improvement in cognitive health, perhaps through greater activity and social engagement giving rise to a cognitively-active lifestyle (Plassman 2010), may strengthen neural circuitry underlying domain-general cognitive skills that contribute to effective listening (Dawes et al. 2015). Repeated test-taking may result in performance improvements on a cognitive task; however, practice effects are not relevant to this review.

A large literature is available on the acute effects of hearing aids in relation to the effort of listening (reviewed recently in Ohlenforst et al. (2017)). This effort is often assumed to be related to the allocation of cognitive resources to the listening task. Hearing-aid interventions are thought to improve the auditory input and free up cognitive resources. Studies have used dual-task procedures, physiological measures of brain activity and subjective self-reports. In the studies employing dual-task procedures, performance improvements on putative cognitive tasks were momentary consequences of cognitive resource reallocation rather than an improvement of cognitive ability per se. More generally, cognitive function was inferred indirectly in most of these listening effort studies; thus, these studies were not included in the review.

One reason to focus on acute effects rather than long-term effects is that the research community has shown considerable interest in the latter (with several studies underway), but it has...
not examined the former. A previous review (Kalluri and Humes 2012) noted overall weak evidence in support of an improvement of cognitive function due to long-term hearing-aid use, although the most rigorous studies in the review had failed to observe such effects. No corresponding systematic review of acute effects has been completed. Acute effects on cognitive function, if related to daily-life listening outcomes, may serve as clinically useful outcome measures. Reviewing the evidence about acute effects may help clarify the nature of long-term cognitive outcomes of hearing-aid use and its mechanisms by informing about the time course of changes in cognitive function.

Our aim was to review the evidence for acute improvements in cognitive abilities that result from hearing-aid use by adults. Accordingly, we defined the following research question for this systematic review: Is hearing-aid use associated with acute changes of cognitive function in adult listeners with hearing impairment? We were also interested in the potential for measurement of cognitive abilities to be deployed in clinical practice, so we originally posed two additional questions. First, are acute cognitive effects of hearing-aid use related to daily-life outcomes for adults with hearing impairment? Second, are acute cognitive effects sensitive to hearing-aid settings? Our search did not yield any studies that addressed these two additional questions, so they have not been discussed further.

We performed the review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. We reviewed studies that included real-life hearing-aid use. We also sought studies that employed hearing-aid simulations in the laboratory so that we could include all experiments that might be informative about immediate effects of hearing aids. Our criterion for effects to be considered acute was a generous 6 months after the onset of intervention. This was, in part, a reaction to the small number of studies that met our inclusion criteria when we initially used a 3-month period. We took account of these selection considerations in defining the inclusion and exclusion strategy according to the Population, Intervention, Control, Outcomes, and Study design (PICOS) criteria for systematic reviews (see below for details).

**Methods**

Before undertaking the review, we registered the study protocol in the International Prospective Register of Systematic Reviews (PROSPERO). The protocol can be accessed at www.crd.ac.uk/PROSPERO/display_record.asp?ID=CRD42017069075. In the protocol, we referred to “changes in cognition”: in this article, we have used the more specific term “improvements in cognition”.

**Search strategy**

Articles for inclusion in the review were identified through systematic searches of five electronic databases (Pubmed, Web of Science, ScienceDirect, GoogleScholar and EBSCOhost). We searched by using terms combining (hearing aid OR amplification OR hearing loss OR hearing impairment) AND (cognition OR cognitive OR attention OR working memory OR recall OR memory OR processing speed OR inhibition) AND (adult or NOT child*) and no date restrictions. We also identified additional articles by combing reference lists of applicable publications, as well as searching in Google using the terms “attention improvement” and “hearing aid” followed by a related article search of authors of papers of potential relevance. We conducted the search originally in May 2017 and then repeated it again in November 2018 in order to include papers published since the original search. After the many thousands of titles and abstracts from the search were reviewed for relevance, the total identified for examination was 29. Seven of these titles had newly emerged from the search that was repeated in November 2018.

**Inclusion and exclusion**

The PICOS criteria helped form the inclusion and exclusion rationale for screening the studies that emerged from our search strategy. Table 1 summarises the PICOS criteria used.

Two authors (SK and BA) independently assessed the titles and abstracts with respect to the PICOS criteria, conferred with each other and excluded several articles because they were deemed irrelevant. There was no disagreement between the two reviewers. The full-text of the remaining articles was then retrieved and assessed against PICOS criteria for further selection to arrive at the final set of articles included in the review.

**Data extraction**

For each included study, we extracted a number of elements about the study design and study results (see Table 2). The extracted elements were chosen according to a checklist that was formulated based on relevance for assessing the acute cognitive effects of hearing-aid use. This comprised authors and publication year, and information regarding details of study design and intervention, participants (number, age and hearing level characteristics), hearing aid features and duration of use, outcome measures, timing of outcome measurement, main findings and significance of findings.

**Quality of evidence**

We evaluated the quality of the evidence supporting acute cognitive effects of hearing-aid use according to the checklist of Downs and Black (1998). This checklist has 27 questions pertaining to the quality of reporting, representativeness, external and internal validity (bias and confounding) and statistical power (see Supplementary Appendix for examples of questions from the checklist). Two authors (SK, KJM) independently assessed each study on each item of the checklist and arrived through discussion at the consensus ratings reported here. Given the

| **Table 1.** PICOS criteria for inclusion and exclusion of studies. |
|---------------------------------------------------------------|
| **Participants** | Adults (18+ years) with any degree of hearing loss; experienced and new hearing-aid users |
| **Intervention** | Use of actual hearing aids in daily life; use of hearing aids (HA) in laboratory setting with no field use; individualised HA simulation in off-the-ear devices (e.g. loudspeaker presentation) or headphones/earphones |
| **Control** | Comparison with a non-HA control group; a control condition of no HA for assessing the effects of HA intervention; a control condition of basic HA for assessing the effects of a specific advanced HA function (e.g. noise reduction) |
| **Outcomes** | Acute cognitive effects with 3–6 months cut-off from onset of intervention; 1+ outcome measures related to cognitive processing, cognition involved in listening (e.g. working memory, selective attention, etc.) |
| **Study designs** | Peer-reviewed experimental studies; randomised controlled trials (RCT) and repeated measures (pre- and post-intervention comparisons) |
## Table 2. Summary of studies that examined the acute cognitive effects of hearing aids on adult users.

| Study                  | No. of groups | Groups                                                                 | N   | Hearing loss | Age in years (M) | Prior HA use | No. of cog. measures | Cog. Measures                                                                 |
|------------------------|---------------|------------------------------------------------------------------------|-----|--------------|------------------|--------------|----------------------|--------------------------------------------------------------------------------|
| Mulrow (1990)          | 2             | Control                                                                | 99  | HFPTA = 51   | 71               | Not reported  | 1                    | A short portable mental status questionnaire
|                        |               | HA                                                                     | 95  | HFPTA = 53   | 73               | None         | 5                    | 2 Proc speed (digit symbol, digit letter), 2 verbal fluency (animals, letters), 1 vocabulary (spot-a-word), V |
| Tesch-Romer (1997)     | 3             | EHI control                                                            | 42  | PTA = 26;   | 71.5             | None         | 5                    | 2 Proc speed (digit symbol, digit letter), 2 verbal fluency (animals, letters), 1 vocabulary (spot-a-word), V |
|                        |               | ENH control                                                            | 28  | PTA = 12;   | 69.4             | None         | 5                    | 2 Proc speed (digit symbol, digit letter), 2 verbal fluency (animals, letters), 1 vocabulary (spot-a-word), V |
|                        |               | HA                                                                     | 70  | PTA = 36;   | 71.8             | None         | 5                    | 2 Proc speed (digit symbol, digit letter), 2 verbal fluency (animals, letters), 1 vocabulary (spot-a-word), V |
| Allen (2003)           | 1             | HA (pre- and post-intervention) with mild-to-moderate primary dementia | 35  | PTA = 59.3 dB HL, std = 9.5 | 84 (range 67–96, std = 6.6) | Not reported, but none reported as current users | 1                    | MMSE                                                                                       |
| Hallgren et al. (2005) | 2             | Young (HA and no HA)                                                   | 12  | Mild-to-moderate | young: 25–45 (M = 36.8) elderly: 65–80 (M = 71.8) | Minimum 1 week | 1                    | SVIPS administered in three different acoustic backgrounds, both A and AV presentation |
|                        |               | Elderly (HA and no HA)                                                 | 12  | Mean PTA (0.5, 1, 2 & 4 kHz) = 56.8 | 70.1 | None | 1                    | MMSE, A                                                                                   |
| Acar et al. (2011)     | 1             | HA                                                                     | 34  | Mean PTA (0.5, 1, 2 & 4 kHz) = 56.8 | 63.1 ± 11.8 | 69.5 ± 8.3 | 1                    | Word-listed learning test (Korean Visual Verbal Learning Test): Recall, Delayed Recall; Recognition |
| Choi et al. (2011)     | 2             | Control                                                                | 11  | Sensorineural HL | 63.1 ± 11.8 | 69.5 ± 8.3 | 1                    | Listening span test, N-back test                                                        |
| Doherty and Desjardins (2015) | 4       | Control (MA & YO)                                                     | 16 (8 MA: 8 YO) | Mild sensorineural, bilateral (i.e. two out of three thresholds were > 26 dB at 2 kHz, > 30 dB at 3 kHz and/or > 35 dB at 4 kHz) | 55 MA: 67 YO | 56.6 MA: 68.7 YO | 2                    | Listening span test, Auditory selective attention task; Auditory reaction time task (CRM), Reading span test, Visual selective attention task (Stroop), Perceptual processing speed (DSTST) |
|                        |               | HA (MA & YO)                                                          | 24 (11 MA: 13 YO) | Mild sensorineural, bilateral symmetric HL | 5464 (M = 60.5) | None | 6                    | Listening span test, Auditory selective attention task; Auditory reaction time task (CRM), Reading span test, Visual selective attention task (Stroop), Perceptual processing speed (DSTST) |
| Desjardins (2016)      | 1             | HA                                                                     | 6   | Mild sensorineural, bilateral symmetric HL | 5464 (M = 60.5) | None | 6                    | Listening span test, Auditory selective attention task; Auditory reaction time task (CRM), Reading span test, Visual selective attention task (Stroop), Perceptual processing speed (DSTST) |
| Castiglione et al. (2016) | 6       | Group A first-time users: bilateral HAs                               | 125 | Group A: bilateral HL, first-time HA use | Group A: 74 | Group A: none | 3                    | DST, MoCA and Stroop                                                                 |
|                        |               | Group B experienced users: bilateral HAs                              |     | Group B: bilatera HL, > 6 mos HA use | Group B: 74 | Group B: > 6 mos | 3                    | DST, MoCA and Stroop                                                                 |
|                        |               | Unilateral HAs, cochlear implant users and normal of comparable age range in other groups |     | > 70 average age in other groups | Group A: none | Group A: none | 3                    | DST, MoCA and Stroop                                                                 |
| Deal et al. (2017)     | 2             | Bilateral HA and paired assistive listening                           | 40  | mPTA = 44 dBHL, mPTA = 47 dBHL | HA: M = 77 | Control: M = 78 | 8                    | Delayed word recall, logical memory A, incidental learning, word fluency (FAS), Boston Naming Test, TMT A & TMT B, DSST |

(continued)
| Study | No. of groups | Groups | N | Hearing loss | Age in years (M) | Prior HA use | No. of cog. measures | Cog. Measures |
|-------|---------------|--------|---|--------------|-----------------|--------------|---------------------|--------------|
| Zarenoe et al. (2017) | 1 | HL with tinnitus and HL without tinnitus | 92 (46 with tinnitus) | 22.3 (SD: 12) | PTA better ear in tinnitus group 32.0 (SD: 9.8) | Unknown | 1 | Reading span test |
| Karawani, Jenkins, and Anderson (2018) | 2 | Bilateral HA | 18 | 42.58 (SD: 7.1) | PTA (0.5–4 kHz) – 40.21 (SD: 8.37) | None | 3 | List sorting working memory test, pattern comparison processing speed test, flanker test |
| Saunders et al. (2018) | 3 | HI users of HAs | 22 | 44.4 (7.8) | Duration of HA experience not documented | 1 | MoCA |
| Saunders et al. (2018) | 3 | HI non-users of HAs | 20 | 36.7 (5.4) | 70.1 (6.3) | 19 | 13.2 (5.6) | 63.2 (6.2) |

Study | Cog. administered | HA fit | HA use | HA duration | Outcome |
|-------|-------------------|--------|--------|-------------|---------|
| Mulrow (1990) | Battery administered at baseline and 4 mos Subset of battery (HHIE and QDS) administered at 6 weeks. | 97% monaural, 98% ITE; subjective benefit | 30% 4–8 h/day, 55% >8 h/day | 4 mos | Significant effect of HA use |
| Tesch-Römer (1997) | Tests administered at baseline; 6-month follow-up | 74% monaural fits, 51% ITE; objective benefit measured | 6.5–7 h/day | 6 mos | No effects of HA use on cognitive function, including when controlled for individual differences in daily usage |
| Allen (2003) | Test administered prior to fitting, and at 4, 12 and 24 weeks post-fitting | Unilateral fits (usually right ear), NAL-R verified with real-ear probe measurements | 75% used daily at week 2, declined to 56% at week 24 | 24 weeks | HA use did not improve cognitive function (mean MMSE decline of 2.0 over the 24 weeks after initial fitting) |
| Hällgren et al. (2005) | Tests were administered in 2 sessions with at least 1 week in between; in each session, all tests were performed 3 times for each background condition. 1/2 subjects used HA for 1st session, no HA for 2nd; vice versa | Bilaterally fitted HA 20 of the 24 participants wore Oticon Digifocus II | Not specified | – | No effect of HA use on cognitive tests |
| Acar et al. (2011) | Tests administered “prior to and 3 months following the use of HA” | No details provided | No details provided | 3 mos | Significant effect of HA use (MMSE increased from 20.4 to 23.0 – both low) |
| Choi et al. (2011) | Tests administered prior to HA fitting; 6-month follow-up | No details provided | No details provided | 6 mos | Speech-related cognitive function in individuals with HL improved after HA use |
| Study                                      | No. of groups | Groups                          | N         | Hearing loss | Age in years (M) | Prior HA use                                                                 | No. of cog. measures | Cog. Measures |
|-------------------------------------------|---------------|---------------------------------|-----------|--------------|------------------|-----------------------------------------------------------------------------|---------------------|---------------|
| Doherty and Desjardins (2015)             |               | Tests administered 4 times over 6 weeks: baseline, session 2 | Bilateral | >8 h/day     | 6 weeks (1.5 mos) | MA and YO participants’ auditory WM function was significantly improved by HA use. | –                   | –             |
| Desjardins (2016)                         |               | Baseline: 3 sessions, 1 week apart; Treatment: 2, 4, 6, 12 and 24 weeks; Withdrawal: 26 weeks | Bilateral | 5-10 h/day (M = 8.33 h/day) | 6 mos (short-term outcomes seen at 2-4 weeks) | Significant improvements on cognitive measures with HA use at the individual level; some participants show better performance when aided, especially on auditory cognitive measures | –                   | –             |
| Castiglione et al. (2016)                 |               | Group A: DST prior to and 1-month after HA fitting. Group B: DST and Stroop in a single session, both aided and unaided. | No details provided | No details provided | Immediate to 1 month | Significant improvement rebaseline on DST at 1-month in Group A. Significant improvement DST aided compared to unaided in Group B. | –                   | –             |
| Deal et al. (2017)                        |               | Baseline and 6 mos              | No details provided | 9.8 h/day | 9.2 h/day | 9.7 h/day | 6 mos | Significant improvement in memory in the hearing intervention group | –                   | –             |
| Zarenoe et al. (2017)                     |               | Baseline and 6 mos              | Unilateral and bilateral fits per clinical best practices | Not documented | 6 mos | Significant improvement of reading span relative to baseline in tinnitus subgroup but not in matched or unmatched no-tinnitus subgroup | –                   | –             |
| Karawani, Jenkins, and Anderson (2018)    | Baseline and 6 mos aided in both experimental and control group | Bilateral fit to NAL-NL2 targets with Widex Dream 440 RIC hearing aids | Daily hearing aid use (9.4 +/− 2) monitored with HA data logging | 6 mos | Improvement in WM scores in experimental group that is not seen in control group; no improvement of attention or processing speed | –                   | –             |
| Saunders et al. (2018)                    | Unaided and aided or test and re-test in the same session | Own HA set to default clinical fit PocketTalker self-adjusted for comfortable listening level None | Not documented | Not documented | Not documented | No significant improvement of MoCA in amplified conditions relative to unaided. | –                   | –             |

No., N: number; M: mean; HA: hearing aid; A: auditory; AV: auditory-visual; V: visual; HFPTAbe: high-frequency pure-tone average better ear; HHIE: hearing handicap inventory for the elderly; QDS: quantified Denver scale of communication function; ITIE: in the ear; h/day: hours/day; mos: months; EHI: elderly hearing-impaired; ENH: elderly normal hearing; PTA: pure-tone average; HFPTA: high-frequency pure-tone average; proc. Speed: processing speed; dig symbol: digit symbol test; SVIPS: speech and visual information processing skills; MMSE: mini-mental state examination; HL: hearing loss; MA: middle-aged; YO: young older; WM: working memory; SSSED: single-subject experiment design; CRM: coordinate response measure corpus (Bolia et al. 2000); DSST: digit symbol substitution test; DSL: desired sensation level; MoCA: Montreal cognitive assessment; DST: digit span test.
relatively small number of studies that passed our inclusion criteria, we deemed it unnecessary to evaluate the risk of bias at the level of outcome assessment pooled across studies as is often done in systematic reviews (e.g. Ohlenforst et al. 2017).

The final step was to rate the overall quality (across studies) of outcome evidence using the quality elements developed by the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) working group: (i) risk of bias, (ii) indirectness, (iii) inconsistency and (iv) imprecision (Guyatt et al. 2011).

Results

The PRISMA flow diagram in Figure 1 shows how studies included in the review were selected. In summary, 13 articles emerged as eligible for the review from an initial pool of 29 articles that we identified from database searching and additional manual searching. This pool of 29 articles was whittled down through application of the PICOS criteria and other factors (see Supplementary Appendix for articles that were eliminated during screening of the full text).

Data extraction

Table 2 summarises the evidence about acute cognitive effects from the included studies. All studies involved older listeners in the age range of typical first-time adult hearing-aid users and sufficient hearing losses to merit the prescription of hearing aids in conventional clinical practice.

Two of the studies were conducted at least two decades ago (Mulrow 1990; Tesch-Römer 1997). One notable feature of these two older studies is the very high proportion of monaural hearing-aid fittings. Two more recent studies in our pool did not
specify if the hearing-aid fittings used were bilateral (Acar et al. 2011; Choi et al. 2011).

Nine studies noted an improvement in cognitive outcome measures. In two of these cases, cognition was assessed using general dementia screening tools that provided little insight about the nature of cognition improvement (Acar et al. 2011; Mulrow 1990). Six studies assessed cognitive function after three or more months of hearing-aid use (Acar et al. 2011; Choi et al. 2011; Deal et al. 2017; Karawani, Jenkins, and Anderson 2018; Mulrow 1990; Zarenoe et al. 2017), a considerable amount of time that is perhaps more relevant to long-term effects rather than momentary or acute effects.

In six studies, within-subject comparisons assessed the cognitive effects of hearing-aid use (Doherty and Desjardins 2015; Desjardins 2016; Hällgren et al. 2005; Zarenoe et al. 2017; Saunders et al. 2018). For example, one of these studies assessed the momentary cognitive effect of amplification by comparing the aided versus unaided performance on an auditory cognitive test at a given point in time (Doherty and Desjardins 2015). In this and two other such within-subject designs that used auditory cognitive tests (Desjardins 2016; Hällgren et al. 2005), acute effects were attributable to improved auditory processing of the acoustic input rather than to improvements in domain-general cognitive abilities that would manifest in tests administered through other modalities such as vision. Within-subject comparisons of two other studies (Castiglione et al. 2016; Zarenoe et al. 2017) yielded improvements of cognitive measures, but these did not have suitable control conditions to rule out practice or placebo effects.

Four of the thirteen studies failed to observe any improvement in cognitive function (Allen 2003; Hällgren et al. 2005; Tesch-Romer 1997; Saunders et al. 2018). It is worth noting that one of these studies was on patients with a diagnosis of primary dementia (Allen 2003), a patient group that is not representative of most users of hearing aids. Another study used experienced users of hearing aids (Hällgren et al. 2005). These users may not readily show the acute improvements that might ensue from a newly enriched auditory experience of new hearing-aid users.

Quality of evidence

Quality of individual studies

Table 3 shows the result of our assessment of the methodological quality of the individual studies according to the checklist of Downs and Black (1998). None of the studies passed our locally determined threshold of quality of 75% of the maximum possible score (range 28–68%). While the quality of reporting and internal validity was generally high, most studies had poor external validity and exhibited selection biases.

The low scores for external validity were most frequently due to inadequate demonstration that subject populations and treatments were representative for the general population (e.g. a single audiologist performed the best fit and fine-tuning of hearing aids for all participants in Acar et al. 2011). The low scores for selection bias were a consequence of non-random assignment, absence of control groups (Acar et al. 2011; Desjardins 2016; Hällgren et al. 2005) and absence of treatment blinding to patient and researcher alike.

Furthermore, information about confounding factors such as prior hearing-aid experience, quality of hearing-aid fitting and amount of daily hearing-aid use was sometimes missing or unaccounted for. Two studies reported that participants had prior hearing aid experience (Hällgren et al. 2005; Castiglione et al. 2016), five studies did not report this information at all (Mulrow 1990; Allen 2003; Choi et al. 2011; Zarenoe et al. 2017; Saunders et al. 2018), while the remainder reported no prior hearing-aid experience. Similarly, confirmation of daily use and information about wear time were sometimes missing, although in the cases where these were reported, daily use generally exceeded 5 h.

Quality of the overall evidence base

There were multiple concerns about overall quality, primarily over risk of bias (from lack of blinding) and indirectness (differences between the study sample and the population of interest). Therefore, the overall quality of outcome evidence was graded as low. Further research is very likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Discussion

The aim of this study was to review the evidence for acute improvement of cognitive abilities due to hearing-aid use by adults. The search identified 13 studies that examined this question directly. Overall, nine studies indicated a significant positive
effect of hearing aids on cognitive function after hearing-aid use of a few weeks while four found no change. This finding of improved cognitive function should be interpreted cautiously for the following reasons:

1. Where cognitive outcomes were significantly improved, the effects were modest in size.
2. Studies reporting positive outcomes used designs generally with low external validity and furthermore, they failed to account adequately for confounders that lead to selection biases. As such, the wider applicability of their positive findings is debatable.
3. Several studies reported positive effects of hearing-aid use on cognitive function after four to six months of hearing-aid use, which leaves unknown if such effects would be seen more rapidly.
4. Low external validity and selection bias characterised all of the studies, so that the generalisability of those studies that did not find an acute effect of hearing-aid use can be questioned. For example, Häggren et al. (2005) did not find an acute effect of hearing-aid use; however, participants in the experiment had prior experience with hearing aids that may have diminished or eliminated any acute effects. For another example, considerable numbers of participants across the studies in this review might have experienced unilateral rather than bilateral fits. Putative cognitive effects may have been underestimated in these participants.

The relatively small number of studies that met our inclusion criteria is somewhat surprising given the significant activity in the audiology research community devoted to exploring links between cognition and hearing. This, however, can be attributed to many articles failing our inclusion criteria because they did not directly assess cognitive functions or satisfy all PICOS criteria.

There is a large body of literature, which did not meet our inclusion criteria, that examines the effect of hearing impairment and hearing aids on listening effort. This literature was recently reviewed by Ohlenforst et al. (2017). These measures of effort are interpreted frequently in cognitive terms. However, we left out these studies because direct links of the listening effort measures to explicit cognitive abilities have yet to be clearly demonstrated (McGarrigle et al. 2014).

Overall, few studies have directly examined acute cognitive effects of hearing-aid use and none have employed designs with high enough quality to unambiguously assess the existence of acute cognitive effects. As such, there is a need for high-quality randomised control trials (RCTs) that directly address the presence of acute cognitive effects. There is especially a need for examining effects at short intervals of a few days to 1–2 weeks of hearing-aid use because there are hardly any studies that have examined such short intervals. Such data will help clarify the cognitive effects of hearing aids and how any such putative effects might be applied in a clinical context.

Conclusions

Thirteen studies were identified in the review and nine reported a small but significant acute improvement in cognitive outcome. However, there are important limitations in the design of many of these studies and the overall quality of evidence is low. Further research, including RCTs investigating changes in cognitive outcome within days/weeks of hearing aid fitting, is very likely to have an important impact on our confidence in answering the review question.

Disclosure statement

The authors report no declarations of interest.

Note

1. ScienceDirect yielded 11,863 results using terms “hearing aid” AND “cognitive function” AND “adult”; Web of Science yielded 284 records using terms Hearing aid (215,003) AND cognition (544,563) AND adult (1,439,003); Google Scholar yielded 401,000 results using terms “hearing aid” AND “adult” AND “cognition” OR “attention”; Using EBSCOhost, the search “hearing aid” OR “hearing impairment” AND “cognition” NOT “child” limited to Scholarly (Peer Reviewed) Journals, Magazines and Reviews returned 167,521 results.

Acknowledgements

The authors gratefully acknowledge the help of Rebekah Bruckner for searching and screening studies for inclusion in the review. They are also grateful to the two anonymous reviewers and the editor for helping improve the manuscript.

Funding

KJM was supported by the NIHR Manchester Biomedical Research Centre.

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