Supplemental Digital Content 1. Protocol systematic review.

Title

Characteristics of Auditory Processing Disorders: A Systematic Review

Context and conceptual issues

Aim of review

To determine the characteristic associated with Auditory Processing Disorders (APD) and suspected APD (susAPD), and to provide a summary of the differences in performance between (sus)APD and typically developing (TD) children on behavioral, physiological and brain measurements.

Stage 1: Identification

Search strategy

The following databases will be searched:

Pubmed;

Ebscohost:

PsycINFO;

Cumulative Index to Nursing and Allied Health Literature (CINAHL);

Educational Resources Information Center (ERIC);

Communication & Mass Media Complete;

Excerpta Medica database (EMBASE).

Studies published from 1954 (studies of auditory processing began in 1954 (Myklebust in Cacace & McFarland, 2009) and 1955 (Bocca, Calearo, Cassinari & Migliavacca in Cacace & McFarland, 2009)), written in English and published in a peer-reviewed journal, containing primary research were initially considered for the review.

Results will be incorporated in a Prisma flow chart (Moher, Liberati, Tetzlaff, Altman, The PRISMA Group (2009)).

Keywords:

Pubmed:

("Auditory Diseases, Central"[Mesh] OR auditory processing[tiab] OR auditory perceptual[tiab]) AND (child[tiab] OR children[tiab] OR adolescent*[tiab])

- We decide to use the MeSH-term one above in hierarchy (MeSH-term "Auditory diseases, central" instead of "Auditory Perceptual Disorders"). Search on the broader term will retrieve articles to that heading as well as to all of the narrower terms indented below.

PsycInfo, Eric, CINAHL, Communication & Mass media complete:

(TI "auditory processing" OR TI "auditory perception" OR TI "auditory perceptual") OR (AB "auditory processing" OR AB "auditory perception" OR AB "auditory perceptual") AND (AB child OR AB adolescent)

EMBASE (until March 15 2012):

"auditory processing", "auditory perception", "auditory perceptual" child:ab OR children:ab OR adolescent:ab OR adolescents:ab.

- Import all possibly eligible studies in Refworks in a separate folder ("Total search").
- Assess exact duplicates and close duplicates in Refworks and remove exact duplicates.

Stage 2: Screening

Step 1) Screening of titles

The titles of studies located and stored in Refworks are screened against the inclusion/exclusion criteria by two researchers (EW & MV).

- Indicate based on the title per Refworks page (in written form on paper) per reference if the study should be included (+) or excluded (-) in the review.

The selection of both reviewers will be compared. When both reviewers have assessed a reference with the symbol "-" the study is stored in a folder "Out". When both reviewers have assessed a reference with the symbol "+" the reference will be stored in the Refworks folder "In on title". When the reviewers have no agreement, the abstract will be opened and reviewed and discussed between the two reviewers. After getting agreement, the reference is stored in the "in on title" or "out" folder.

Inclusion criteria title

1) Published in English
2) Addressed factors in title about:
    - Auditory Processing in combination with deficit(s), impairment(s), problem(s), difficulties, or disorder(s)

    The following terms are also considered for inclusion:

    - Auditory problem(s)
    - Auditory perceptual or auditory perception
    - Auditory (dys)function
    - Auditory abilities
    - Listen(ing)
    - Speech perception or processing

<u>Step 2) Screening of abstracts</u>

The abstracts of the studies stored in the Refworks folder "In on title" will be screened against the eight inclusion/exclusion criteria by two of the three researchers (EW & MV or EW & ML).

- Indicate based on the abstract (in written form on paper) per reference if the study should be included (+) or excluded (-) in the review. In case of exclusion: state the

reason of exclusion with writing down the number corresponding with the inclusion/exclusion criteria (1-8) where the study does not meet the inclusion criteria. Abstracts that meet the inclusion criteria will be moved to the Refworks folder "In on abstract". When in doubt, the abstract will be reviewed and discussed between the three reviewers. As it is not always obvious from the abstract whether the study satisfied the inclusion criteria, remaining studies are read more extensively for eligibility (step 3) by one of the three reviewers (EW, MV and ML).

Inclusion/exclusion criteria abstract

1) Published in English
2) Addressed factors in abstract about:
    - Characteristics of APD, susAPD or children at risk for APD, in the presence of normal hearing.

    The following terms for APD are also considered for inclusion:

    - (Central) auditory processing disorder(s)
    - Auditory processing deficit
    - Auditory processing disease
    - Auditory perceptual disorder(s)
    - Auditory perception disorder(s)
    - Acoustic perceptual disorder(s)
    - Auditory listening problems
    - Central auditory dysfunction
    - Listening disorder(s)
    - Listening difficulties
    - Speech perception problem(s)
    - Speech perception disorder(s)

4) Participants must be under the age of 18 years because the final step in structural maturation of the auditory cortex occurs in later childhood, between the ages of six and twelve (Moore & Linthicum, 2007).
5) Studies in which participants with brain damage or other deficit(s) participate, will be excluded (neuropathy, children with cochlear implants, children with down syndrome or another syndrome, neonatal children, children with peripheral hearing loss, children with chronic otitis media, children with brain damage).
6) Primary research (randomized controlled trials, experiments, quasi-experiments, Meta-analyses, cohort studies, case-control).
7) Published in peer-reviewed journal.
8) Books, book chapters, dissertations or case studies or case-series will be excluded.

Stage 3: Eligibility

Step 1) Full-text articles assessed for eligibility

The references in the Refworks folder "In on abstract" will be divided between the three researchers (EW, MV & ML). They will individually read and review the papers and accurately checking them against the criteria for inclusion. After that, the first reviewer (EW) checked the eligibility of the second reviewer (MV) and third reviewer (ML) and vice versa. All reviews are discussed in a consensus meeting and any uncertainty about a reference will be discussed among the three researchers. All studies that meet inclusion will be stored in the folder "Systematic Review: final search".

Procedure

The following should be present in the study:

1) Description of the study design and research method.
2) Description of the study population: a group of children with (suspected) APD or children at risk for APD and a control group (typically developing children or

normative group). When the study contains a normative group, the normative group must be described in detail (information about number of participants and age range must be available). When the study contains a control group in which children participate who were initial referred to a clinic because of listening difficulties but were subsequently classified as non-APD, the study will be excluded from the review.

3) Description of the tests used in the study to determine if there were differences between children with (sus)APD and their TD peers.
4) The focus of the study needs to be on children with (sus)APD. Children in the experimental groups have listening complaints in the presence of normal hearing. In the study, authors need to speak about APD (or one of the synonyms of APD, described by stage 2). When the focus of the study is on children with another developmental disorder, such as Learning Difficulties (LD), Dyslexia, Specific Language Impairment (SLI), ADHD or Autism, the study will be excluded.
5) Study meets the research question: contains information about characteristics or performance of children with (suspected) APD on behavioral, physiological or brain measurements in comparison with their TD peers. Characteristics or performance of children with clinically diagnosed APD, susAPD or at risk for APD, in the presence of normal hearing.
6) In the result section the following needs to be present: a comparison between the performance of children with (sus)APD and typically developing children.
7) The study meets all the criteria described at stage 2: screening of abstracts

<u>Step 2: Full-text assessed for methodological quality</u>

Each included study will be independently reviewed and evaluated for methodological quality by two reviewers (EW & MV or EW & ML) with the ASHA's levels-of-evidence (ASHA's LOE) scheme (Mullen, 2007). The two reviewers, blinded to each other's results, appraised

each study on the basis of the quality indicators: study design, blinding, sampling/allocation, group/participant comparability, outcomes, significance, and precision (see Supplementary Table 1).

Explanation ASHA's LOE system (adapted from Mullen, 2007 & Fey et al., 2011)

Study design: design of the study is reported or a description of the design is in detail described. Studies with an (sus)APD group and a control group will be regarded as a case-control study. Studies with more than one experimental group and a control group and studies with normative groups will be regarded as a cross-sectional study.

Blinding: researcher, testers (observers) and/or test scores were masked with respect to the child's group assignment. The tester/researcher does not know in which group the child participated (experimental or control group).

Sampling / allocation: participants were selected at random or were assigned randomly to groups. The recruitment and selection procedure of participants was descripted in detail. The main characteristics of the groups are described in detail; the study contained a table with a clear description of the demographic characteristics of the children in the different groups (e.g., gender, age range, mean age, socioeconomic status, type of school, language abilities).

Group / participant comparability: appropriate comparison between groups; homogeneous group at the start of the study (between-subject design) or well-described subjects (within-subject design). Inclusion and exclusion criteria of the study population are well described. Matching is described. Differences between subjects are described in detail. Only yes when the subjects within groups are well described (with participant information in a table) and are comparable at the following factors: hearing; language, intelligence and reading abilities and the presence of comorbid disorders.

Outcomes: clearly defined how main outcomes will be measured. The used measurements were clearly described and explained. Information about reliability and validity is included in the description of the measurements or reference to information about reliability and validity is included. The validity and reliability is reasonable when the used measurement is described in detail and when there are no concerns about the reliability of the measurement.

Significance: a statistical test was reported and p-values are reported or calculable.

Precision: an effect size, such as *d*, is reported along with confidence limits surrounding *d*. When effect size and confidence intervals were not reported, the study provides sufficient descriptive statistics (sample size of each group, means and standard deviations (SD)) to calculate *d* and confidence limits around it.

The quality assessment must be saved per study in a standard formatted excel file (available on request from the first author). All discrepancies between the reviewers will be discussed and resolved by consensus between the three reviewers in a consensus meeting.

Stage 4: Included

Data extraction and analysis

Data will be extracted from the included studies by two reviewers (EW & MV or EW & ML). From the included papers details of participants, experimental group, control group, used measures, outcomes will be extracted and compiled in the standard formatted excel file.

References

Bocca, E., Calearo, C., Cassinari, V., & Migliavacca, F. (1955). Testing "cortical" hearing in temporal lobe tumors. *Acta Otolaryngolgica, 45*, 289-304.

Fey, M. E., Richard, G. J., Geffner, D., Kamhi, A. G., Medwetsky, L., Paul, D., … Schooling, T. (2011). Auditory processing disorder and auditory/language interventions: An evidence-based systematic review. *Language, Speech, and Hearing Services in Schools, 42*(3), 246-264. doi:10.1044/0161-1461(2010/10-0013).

Moher D., Liberati A., Tetzlaff J., & Altman D. G., The PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine 6*(7), e1000097. doi:10.1371/journal.pmed1000097.

Moore, J. K., & Linthicum, F. H. (2007). The human auditory system: A timeline of development. *International Journal of Audiology, 46*, 460-478.

Mullen, R. (2007). The state of the evidence: ASHA develops levels of evidence for communication sciences and disorders. *The ASHA Leader, 12*(3), 8-9, 24, 25.

Myklebust, H. (1954). *Auditory disorders in children*. New York: Grune & Stratton.