**Best ear hearing level, time factors and language outcome in Swedish children with mild and moderate hearing loss with hearing aids**

Birgitta Sahlén, Tina Ibertsson, Lena Askér-Árnason, Jonas Brännström and Kristina Hansson

Department of Clinical Sciences, Lund, Logopedics, Phoniatrics and Audiology, Lund University, Lund, Sweden

**ABSTRACT**

**Aim:** The risk for language disorder is high in children with all levels of hearing loss (HL). Early identification and intervention should be as important for children with mild HL as for those with more severe HL. Despite new-born hearing screening, a recent survey of speech language therapist services in southern Sweden indicates that children with mild and moderate HL are severely neglected when it comes to language assessment and language intervention. In this study we explore associations between Best Ear Hearing Level (BEHL), time factors and language skills in Swedish children with HL with hearing aids (HA).

**Method:** Participants were 19 children with mild HL (BEHL 23–39) and 22 children with moderate HL (BEHL 40–70) aged 5–15 years. Information on age at diagnosis and at HA fitting were collected. The children performed a nonword repetition and a sentence comprehension task.

**Results:** The time elapsed between diagnosis and fitting with HA was longer for the children with mild HL. Participants with mild HL received their HA significantly later than children with moderate HL. No association between BEHL and the two language measures was found, and language skills were not better in children with mild than moderate HL. 17% of participants performed below cut-off for language disorder on both language measures.

**Conclusion:** Given the risk for long-term academic and social consequences of even mild HL delayed HA intervention for children with HL leads to serious concerns by families, clinicians, and pedagogues.

**Introduction**

Children with sensorineural hearing loss (HL; mild < 40 dB Best Ear Hearing Level (BEHL) and moderate/severe 41–70 dB BEHL) with hearing aids (HA) have attracted increasing attention in recent research. This is an appropriate development given that they outnumber children with severe/profound losses [1–2].

In Sweden, new-born hearing screening started to be implemented in the late 1990s but as late as 2006 there were still regions that had not started the process of implementation. The clinical guidelines in the Swedish Program for health surveillance of preschool children recommends hearing screening at age 8 months and at age 4 and has recommendations for when to refer to an audiologist [3]. Communication with researchers and clinicians in Sweden within the field indicates that it is unclear whether and what services are offered to children with mild/moderate HL, and there seems to be a considerable difference geographically. For example, a recent unpublished survey of speech language therapist (SLT) services in southern Sweden indicates that children with mild/moderate HL are severely neglected compared to children with profound/severe HL when it comes to language assessment and language intervention.

It is of interest to investigate the time factors age at diagnosis and age at HA fitting and how they are associated with degree of HL and language skills in a Swedish population of children with HL. We need to have a clearer picture in order to see if there are implications for changes of clinical practice, both with respect to paying more attention to mild/moderate HL early on, timing for fitting with HAs and providing SLT services. In the present study, we, therefore, explore the association between language skills, BEHL, age at diagnosis and at HA fitting, and signs of risk for language disorder in 19 Swedish-speaking children with mild and 22 children with moderate/severe (henceforth moderate) HL with HAs.

In research studies of children with HA groups are often mixed, consisting of children with varying degrees of HL, from mild to severe, which makes it difficult to isolate possible effects of different degrees of HL and time factors, such as age at diagnosis and age at fitting with HA, on language skills. Many studies have found that age at diagnosis and age at fitting with HA are important predictors of language outcome in children with HL at the group level [4–6]. Earlier identification of HL through newborn hearing screening in combination with early fitting and intervention...
for children with HL have indeed resulted in a better outcome for many children [4,5]. Still, there are indications that many children with HL receive their first HA after age five. For example, according to Australian Hearing [7], out of those children who received their first HA in 2014 only 13% were aided in their first year of life, whereas 35% of them were 5–9 years old at the first fitting. There is a range of reasons for late fitting despite the HL being detected at newborn hearing screening [8]. Many of the children receiving their first HA in Australia at age 5–9 have mild losses, 89% of those born during 2005–2009. Also, Fitzpatrick et al. [9] in a study of children with mild HL in Canada found that in about 50% HA fitting was delayed, in particular for early identified HL. This may, according to the authors, be due to a range of external factors (social, economic, organisational) but also within-child factors (etiological, medical).

Although time factors, like age at diagnosis and age at HA fitting, are of indisputable importance, they are not reliable as predictors of language outcome at the individual level [10], and their importance is still discussed. Yoshinaga Itano et al. [11] found that the combination of early screening (1 month), identification (3 months) and intervention (6 months) contributed significantly to vocabulary learning in children with bilateral HL aged 8–39 months. On the other hand, Pimperton et al. [12] in a study of teenagers who had been exposed to universal newborn hearing screening compared to a group who had not, did not find convincing evidence of the effect on language outcome of early screening. A multifactorial background is today assumed by most researchers. Language outcome depends on an interaction between a range of risk factors and protective factors within the child (e.g. linguistic/cognitive, medical, and genetic) and in the environment in children with HL as well as in hearing children [13,14].

Several recent studies show that degree of HL is associated with language outcome [4–6,15], perhaps in particular if taking into account what information is audible and usable in the speech signal as can be estimated using for example the Speech Intelligibility Index [16–17]. But even if there is an association between degree of HL and language outcome, it may not necessarily be proportional, as for example indicated in the large within-group individual variation. Thus, children with all levels of HL risk atypical language development or language disorder. Of children with mild HL, around 30% have been reported to fail at least one school grade [18]. If children with mild/moderate HL, for some reasons, are missed in new-born hearing screening, if HA fitting is delayed and thereby also the provision of audiological intervention and services, including professionals’ encouragement to consistently use HA/s, this is, indeed, problematic.

Research shows that language development and academic success of children with even mild HL (below 40 dB BEHL) are at considerable risk if they do not use HAs [19–21]. There is also a risk that they don’t use their HAs if the recommendations from clinicians do not sufficiently emphasize the importance of consistent usage of well-fitted HAs [6,22].}

It is essential to know how high the prevalence of language difficulties is in this group to be able to identify which children are at risk for persistent language disorder. Hansson et al. [23] found that the performance in approximately 50% in a group of 5–8-year-old children with mild and moderate HL and HAs indicated a risk for language disorder. Studies of children with cochlear implants (CI) also indicate a higher prevalence of language disorder than in the general population, where it is around 7% [24,25]. For example, Geers et al. [26] found that around 1/3 of children with CI had persistent language difficulties at age 10. Hansson et al. [27] found that at least 50% of children with CI in the age range 5–8 performed below cut-offs for language disorder. In the present study, we investigate the proportion of children with mild and moderate HL performing below the cut-off for language disorder on language tests, in relation to time factors and degree of HL.

The basic assumption in the present study is that skills, which are considered clinical markers and prognostic factors for hearing children with developmental language disorder (DLD; [28] can help us to improve prognostic accuracy with respect to language outcome for children with mild and moderate HL. DLD is a condition where children have language learning difficulties despite normal hearing and otherwise typical development [24,28]. The origin is multifactorial and since such difficulties with language learning can co-occur with HL, it is even more difficult to determine the effects of the HL. The most well-researched clinical marker for language disorder is nonword repetition (NwRep) also for Swedish children. This is a task where children are asked to repeat a non-word (i.e. a made-up word such as spletbelisk). The task is considered to index implicit phonological processing in children with normal hearing [29]. There is strong evidence that NwRep is a clinical marker of DLD since the task has high accuracy in correctly identifying which children have and which children do not have DLD (for Swedish-speaking children, [30]). NwRep is often assessed in studies of children with HL. It is a task that is often reported to be related to hearing thresholds and speech perception [27,31], but the task is also associated with higher level processing skills related to lexicon, grammar and working memory capacity. NwRep thus measures constraints on linguistic input as well as output in a child and is only one, but important, way of modeling the challenges that children meet in language development.

Language comprehension is a complex skill, where perceptual, linguistic (phonology, grammar, lexicon) and cognitive abilities (executive functions in particular working memory) interact. Language comprehension is often assessed by spoken sentence comprehension. The grammatical complexity of sentences in a task administered auditorily strongly influences listening comprehension. Difficulties with receptive and expressive grammar represent important areas of weaknesses in children with normal hearing and DLD. We, therefore, chose to use a well-known sentence comprehension assessment, the Test for Reception of Grammar (TROG; [32]) in the present study. Performance
on language (listening) comprehension has turned out to be an early predictor of more severe language disorder in hearing children [33–35].

In the present study we aim at exploring the following:

- the performance of children with mild and children with moderate HL on NwRep and TROG in relation to data from children with normal hearing
- the associations between better Ear Hearing level (BEHL), timing of diagnosis and HA intervention, NwRep and spoken sentence comprehension
- the characteristics of children performing substantially below and above cut-off for DLD.

**Materials and methods**

**Participants**

Participants were 41 children, 22 boys and 19 girls, with bilateral sensorineural mild or moderate HL in the age range 4;11–15;10 (years;months; mean age 9;4, SD 31.38 months). Their pure tone average BEHL for frequencies 500, 1000, 2000 and 4000 Hz ranged from 23 to 70 dB HL and they were all binaurally fitted with HA. Age at diagnosis ranged between 0;0 and 4000 Hz and 70 dB HL and they were all binaurally fitted with HA. Age at diagnosis ranged between 0;0 (years;months) and 7;0, age at HA fitting between 0;7 and 10;0 and time between diagnosis and HA fitting between 0 months and 5 years. The children had used their HAs between five months and ten years and two months at the time of assessment. Medians, minimum and maximum values for these background variables are shown in Table 1. BEHL and time factors were retrieved from medical case files, with parent permission. Aetiology was unknown in most cases, hereditary in at least ten cases, and in a few cases the aetiology was congenital and unknown, but probably due to ototoxic medicine, or connexin 26. Most of the children with HL were recruited from ENT clinics in the south of Sweden, while some of the children were recruited from a school for children with HL (oral speaking, following mainstream curriculum). The children were participants in different research projects including children with mild/moderate bilateral, sensorineural hearing impairment with HA and were selected as participants in the present study if data existed from NwRep and sentence comprehension assessments [23,36–38]. The children were born between 1989 and 2007. Only six children were born in 2006 and later and thus the great majority had not undergone newborn hearing screening.

Nonverbal ability was judged to be within normal limits for all participants according to teachers’ and parents’ reports. The main mode of communication was spoken Swedish for all participants. The majority of the children were in mainstreamed preschool or school classes and only a minority were attending classes for children with HL. Those classes have a syllabus equivalent to classes in mainstream schools. According to the parent report, all participants were using their HAs in everyday life when the study was conducted.

**Nonword repetition task and data**

The children’s implicit phonological processing skills were assessed with a NwRep test. Data were collected for different research projects at different points in time. The NwRep test for Swedish underwent development during this time. Therefore, two different versions of a Swedish NwRep test were used, both consisting of 24 nonwords [39,40]. Reference data from children with normal hearing and typical language development for each of the tests showed that the two tests are comparable in the degree of difficulty.

The words were administered from recordings in quiet surroundings. The sound presentation level from the computer was individually adjusted to a level that each child found comfortable. Each word was presented only once, and the children were instructed to verbally repeat each word. The children’s responses were recorded and transcribed.

Performance was computed as the percentage correctly repeated consonants (PCC) in the correct position in the target words. Minor articulation errors (lisping and rhotacism) were scored as correct, but phoneme substitutions were scored as incorrect.

To obtain scores adjusted for age, and to compensate for the fact that two slightly different tests were used a relative score was computed. The relative score is based on means and standard deviations in reference populations of children with normal hearing for each of the two versions of the NwRep test [41]. A score of 5 represents a performance ±1 SD from the mean percentage consonants correct of the reference group. A score of 4 corresponds to performance below −1 SD in the reference population, a score of 3 below −2 SD, a score of 2 below −3 SD, and a score of 1 to −4 SD below the reference population.

Reliability for transcription of the nonwords was >88% identical transcriptions by two independent judges on a phoneme-by-phoneme basis in the different projects and >97% agreement on whether the nonwords were correctly produced or not.

**Table 1.** Minimum, maximum and median values for age (in months) at assessment, BEHL, age at diagnosis, age at HA fitting, time between diagnosis and HA fitting and time with HA for the two groups.

| Variable                        | Mild HL (N = 19) | Moderate (N = 22) |
|---------------------------------|-----------------|-------------------|
|                                | Min–max         | Median            | Min–max              | Median            |
| BEHL (dBHL)                    | 23–39           | 32.5              | 40–70                | 50.0              |
| Age at assessment (months)     | 59–190          | 121.0             | 60–156               | 108.0             |
| Age at diagnosis (months)      | 0–84            | 51.0              | 0–55                 | 40.0              |
| Age at HA fitting (months)     | 15–120          | 55.0              | 7–57                 | 42.0              |
| Time between diagnosis and HA fitting (months) | 0–60 | 6.0 | 0–9 | 1.0 |
| Time with HA (months)          | 5–114           | 60.0              | 13–122               | 74.0              |
Language comprehension task

The children’s language comprehension was assessed using a test tapping sentence comprehension, the Swedish version of TROG [32,42]. The test is administered face-to-face. The test leader reads a sentence and the child’s task is to listen and point to the correct picture out of four, which matches the content of the sentence. The test consists of 80 test items, arranged in 20 blocks, each focusing on a specific grammatical structure/form with increasing complexity. The maximum score is 20 and the child has to respond correctly to all four items in a block to score correct. The raw scores were transformed to percentile scores, which are the scores reported.

Procedure

The assessments took place in a quiet room and were carried out by either an SLT or an audiologist. The examiners were familiar with the tests and the testing procedure from several other studies and were well acquainted with children with HL. The children wore their HAs during assessments.

Statistical methods

The Shapiro–Wilk test of normality was significant for both language measures, as well as for age at HA fitting and time between diagnosis and HA (w(41) = .519–.941, p = .000–.035). Therefore, Spearman Rank correlations were used to investigate associations between language and time factors. Correlations .10–.29 were considered weak, .30–.49 moderate and .5 and above strong, according to Cohen’s convention [43]. Mann–Whitney U-Test was used to compare children performing below and above cut-off for language disorder.

The research projects were approved by the Regional Ethical Review Board.

Results

Group level language performance and correlations with BEHL and time factors

As a group, the participants score two SD below reference data from children with normal hearing of the same age on NwRep, i.e. below cut-off indicating language disorder [41,44]. In contrast, group mean performance on TROG is well above the 10th centile, i.e. above cut-off for significant difficulties with language comprehension. However, individual variation is extreme: 1–5 on the relative score for NwRep (median 3) and percentile 1–95 on TROG (median 25).

Spearman rank correlations (Table 2) show that age at assessment is significantly associated with time with HA and performance at TROG. Further, BEHL is significantly associated with gender, the girls having higher BEHL, i.e. more severe HL, than the boys. BEHL is also significantly and negatively associated with age at HA fitting so that children with more severe HL tend to have received their HAs at a younger age. Finally, BEHL is also significantly and negatively associated with time between diagnosis and HA fitting, i.e. the more severe the HL, the shorter the time interval. Time between diagnosis and HA fitting is not associated with any of the language variables. Performance at NwRep is not significantly associated with BEHL or with any of the time variables. Performance at TROG is significantly associated with age at assessment and with time with HA, but not with BEHL.

* p < .05. ** p < .01. *** p < .001.

BEHL is thus associated with some of the time factors, indicating that higher BEHL (poorer hearing) entails earlier and quicker HA-interventions, but it is unrelated to language scores.

Figure 1 shows the association between BEHL and time between diagnosis and HA fitting, which are moderately associated (r = .45). Children with a long time between age at diagnosis and receiving HAs tend to have mild HL, whereas children with a short time between age at diagnosis and receiving HAs vary largely in BEHL. All girls, except one, were fitted within one year after diagnosis.

Investigating the distribution of NwRep and TROG performance against BEHL, we see that individual variation is extremely large, as illustrated in Figures 2 and 3.

Figure 2 shows the distribution of NwRep scores in relation to BEHL for all participants, to further illustrate the influence of hearing level on language skills in the group with moderate HL. The range in BEHL for children scoring low on the NwRep test (score 3 or less) is very large and similar to the range for those scoring high (more than score 3). Boys and girls were evenly distributed in low/high NwRep scores.

Similarly, Figure 3 shows BEHL against TROG percentiles. Again, the lack of association between the two variables is apparent. There was a similar distribution of girls and boys scoring below percentile 10.

These figures further show the heterogeneity in the group and lack of strong associations.

Table 2. Spearman rank correlations between time factors and language skills.

|                  | BEHL | Age | Age at diag | Age at HA | Time btw diag and HA | Time w HA | NwRep | TROG |
|------------------|------|-----|-------------|-----------|----------------------|----------|-------|------|
| Gender           | .39* | .22 | -.00        | -.15      | -.33*                | .34*      | -.16  | .01  |
| BEHL             | -.25 | -.25| -.51**      | -.16      | -.45**               | .16       | -.28  | -.02 |
| Age              | .06  | .30 | .83***      | .10       | .76***               | .07       | .38*  | .11  |
| Age at diag      |     |     |             | -.17      | -.19                 | -.02      |       |      |
| Age at HA        | .19  | .33*| .07         | .06       | .12                  | -.02      |       |      |
| Time btw diag and HA | .20 | .05 | .40*        | .05       | .40*                 | .28       |       |      |
| Time w HA        |     |     |             |           |                      |           |       |      |
| NwRep            |     |     |             |           |                      |           |       |      |

*p < .05. **p < .01. ***p < .001.
For example, one of the children with the highest NwRep score (i.e. within 1 SD below reference data or better) is the child with a BEHL at 70 dB, thus classified as borderline moderate/severe. This child was diagnosed at birth (probably new-born hearing screening) and fitted with HA at 7 months. The child with BEHL 26 (i.e. mild/minimal HL) has very low Nwrep (>4 SD below reference data) was diagnosed at 18 months but did not receive HA until age 4:6.

To further illustrate the lack of association at the individual level between BEHL and language outcome, the highest performers were six children who scored 5 on NwRep and at or above 50th centile on TROG. Their BEHLS varied between 31 and 70.

**Characteristics of children performing substantially below and above cut-off for language disorder**

Most of the participants, 23/41 children (56%) performed more than 2 SD below age references on NwRep and 10/41 (24.4%) performed at or below percentile 10 (more than 1.25 SD below age norm) on the language comprehension test. Seven of the participants, four girls and three boys (17%) performed below cut-off for DLD on both tests. Three of these children can be categorized as having mild HL (BEHL 26–38) and four as having moderate HL (46–63), representing the whole spectrum of BEHL of the group (23–70). Thus, BEHL did not differ between the lower and higher performing subgroups. If low performance
(score 3 or less) in NwRep in combination with low performance on TROG (percentile 10 or below) is taken as indicative of potentially persistent language disorder, then the risk for persistent language disorder is considerably higher than in the general population (where it is estimated to 6–7% in preschool years and 1–2% in school years, above age 7 [24]). The median and min-max values for all variables for these seven children in comparison with the remaining 34 children are shown in Table 3.

The variables where the two subgroups differed significantly were age at assessment (effect size $r = .33$), time with HA (effect size $r = .38$), NwRep score (effect size $r = .39$) and TROG centile (effect size $r = .61$). The children in the below cut-off group were younger, had had their HAs for a shorter time and performed significantly lower in relation to peers with normal hearing on both NwRep and TROG. Effect sizes in the three first cases were medium and for TROG centile large.

### Summary of results

- Individual variation is very large with respect to both BEHL and the time factors related to age at diagnosis and at HA fitting.
- Children with mild HL tend to have received their HAs at a later age and the time between diagnosis and HA was relatively long.
- Neither BEHL nor time factors are significantly associated with the language measures, except that children who have had their HAs for a longer time tend to perform better.
- At the group level, these children with mild and moderate HL perform well below age peers on NwRep, but not on TROG. However, individual variation is extreme on both language measures.
- Children who perform below cut-off for language disorder on both language measures tend to be younger.
than those who do not and to have had their HAs for a shorter period of time. Otherwise, they do not differ significantly from the rest of the group on any of the background measures.

Discussion

We explored the associations between BEHL, time factors related to age, age at diagnosis and HA fitting and two aspects of language skills (NwRep and sentence comprehension) in Swedish children with mild and moderate HL with HAs. Here, BEHLs corresponding to 40–70 dB are referred to as moderate HL. The WHO classification of severity of HL has been changed to BEHL 26–40 dB for mild and 41–60 dB for moderate HL. Since most of our participants (31) were diagnosed before 2004, we kept the classification used at the time they were diagnosed.

Our main finding is that participants with mild HL (below 40 dB) received their hearing aids significantly later than children with moderate HL. This is in line with international studies e.g. Australian Hearing [7] and with the findings of Walker et al. [45] in the US. Whatever the reasons for the late fitting in mild HL (etiological, medical, social, or organisational), there is today ample evidence for the risk of language learning difficulties and academic shortcomings in mild HL [6,18,22]. Further, we also found that the time elapsed between diagnosis and fitting with HA was longer the milder the hearing loss. Children who had worn their HAs for a longer time were better at language comprehension. Given that we used a standardized score for language comprehension performance the positive correlation between time with HA and language comprehension score indicates that the trend may at least not be towards widening the gap to peers. The same pattern of a narrowing gap associated with length of device use has been reported in several longitudinal studies of language outcome in children with HL [4,6,21].

The lack of association between BEHL and the two language measures was not unexpected given earlier studies indicating the high risk for delayed language development in children with all levels of hearing loss (see Sahlén et al. [46]). Evidence is, however, relatively inconclusive as for the association between NwRep and BEHL in children with mild and moderate HL. It is important to recognize that the present study would have benefitted from information that can be used to determine the audibility of the speech signals in these children. There are previous studies that suggest that nonword repetition depends on the audibility of the nonword speech material to a high degree as children with better audibility of the speech signal showed better ability to process and store individual phonemes [17]. This ability is essential for the performance in tasks like nonword repetition which means that it is possible that measures other than BEHL, such as aided audibility of speech and device use, most likely are better indicators of the quality of the input to the child. Furthermore, maybe with an audiovisual task (i.e., presentation of the nonwords is both audio- and videorecorded), where hearing is less implicated, we might have found stronger or different associations. Al-Salim et al. [47] created an audio-visual version of a NwRep task relating it to measures of vocabulary, working memory and executive functions. Based on the results from a large number of children with the different hearing status they conclude that this task may be better able to discover language learning difficulties not directly dependent on hearing thresholds or speech audibility. Individual data illustrate the well-known and considerable heterogeneity among participants in language outcome and support the fact that BEHL is a poor indicator of language outcome and need for language intervention. Individual performances on the phonological processing task indicate that the task mirrors other factors than BEHL; one of the children with the highest NwRep had BEHL 70, whereas the child with BEHL 26 had very low Nwrep (>4 SD below reference data). Again, it is evident that we would have needed better control of audibility, both during the assessment and with respect to aided audibility of speech and device use, in order to be able to draw any conclusions. We can only note that the NwRep task was administered in the same way as it is done in clinical practice at present and that changes in the clinical protocol may thus be warranted.

Participants were collected from several earlier studies to reach a reasonable number. In the group with mild HL, we found a majority of boys. A longer period between diagnosis and fitting could theoretically be a greater disadvantage for boys, who mature later and have a higher risk for language disorder than girls. However, neither group level data nor individual data give any indication of an association between gender and language measures.

Our results show that seven (17%) of the whole group of 41 children (16% in the group with mild HL and 18% in the group with moderate HL) performed substantially below cut-off for LD on both language measures. Comparing these participants with the rest we found a significant difference with large effect size for sentence comprehension (TROG) and medium effect size for phonological processing. We do not suggest that these seven participants actually have LD, but that they may be at risk for persistent difficulties, which may be caused by hearing ability, but not measured as BEHL. The seven lowest performing children were significantly younger and had had their HAs for a shorter period of time. We thus do not know if all or some of them will restore their problems with age. There is no clear borderline between delay and disorder. Children showing lower performance need intervention, irrespective of whether it is a delay or a disorder, and irrespective of whether degree of hearing loss is a determining factor. Without intervention the “delay” may become a disorder. The explanation for poor language outcome is likely multifactorial, meaning that there may be weaknesses in several cognitive and language processing skills that support language learning. The degree and extent of the hearing loss is one important underlying factor since it is crucial for the quality of the input to the child. Identifying DLD when HL is present based on a task like NwRep, that is heavily audibility-dependent, calls for caution. The recommendation from the CATALISE project
on the diagnosis of DLD [48] is, therefore, to refer to lan-
guage difficulties in children with HL as “language disorder
associated with HL.” Although a diagnosis of LD is never
based only on formal tests, performance below the 10th per-
centile is clearly an indication of risk. The lack of significant
differences in this study between groups performing above
and below cut-off regarding BEHL or fitting age must be
considered with caution since the groups are very small. A
larger population and follow-ups at later ages are needed to
determine the prevalence of persistent LD in children
with HL.

The rationale for choosing NwRep and TROG as lan-
guage tests was that nonword repetition has high sensitivity
and specificity for DLD in Swedish-speaking children [30]
and language comprehension has been found to be a signifi-
cant predictor of more severe difficulties [33–34]. We had
expected an association between NwRep and TROG but
found no significant association. Both are audibility depend-
ent, but NwRep more so since it is purely auditory and
there is no or at least much less supporting linguistic con-
text than in TROG. Both tap working memory, but for sen-
tence comprehension other skills are also required, for
example, to process the lexical and grammatical content,
tapping more into complex working memory (the ability to
simultaneously process and recall information [49]). Nonword repetition can be considered a lower-level skill. At
the individual level, however, children with low sentence
comprehension also performed low on NwRep more than
the reverse, as also found by Sundström et al. [31].

In Sweden, there are guidelines for new-born, preschool
and school-age hearing screening [3]. There are, however,
no national clinical guidelines for audiological or SLT inter-
vention practices once children are diagnosed and fitted
with HAs. Although no documentation exists, our impres-
sion is that there are considerable differences between differ-
ent parts of the country as to whether, and what services
are offered. This creates frustration in families, for clinicians
and pedagogues around the child with HL. According to a
recent survey of SLT services offered in the South of
Sweden [50], children with HL and HA do not get the serv-
ices they need when it comes to language assessment and
intervention. However, new efforts with a quality register of
children with HL including children with mild and moder-
ate HL have recently been undertaken [51]. Since 2019
audiological clinics are invited to register all children in the
age range 0–18 years with a worst ear hearing level >29 dB
on either ear. Data are registered at start and after each fol-
low-up in the program. Language assessments are carried
out at age 3, 6, 10 and 15 years by an SLT.

The BEHL threshold for what is considered disabling
hearing loss according to WHO is different for adults and
children (greater than 40 dB vs. 30 dB). The participants
were all assessed at ages 5–15 years. They thus have many
years in mainstream school and working life ahead of them
in contexts with challenging listening conditions. Younger
children are more vulnerable to degraded source signals
both in quiet and in noise [52]. Degraded signals may per-
tain to within-individual limitations as HL and/or language
disorder or to external factors like background noise. Children with HL have documented weaknesses with listen-
ing in noise [53–54]. A recent study [55] found that dosage
of HA use (a measure of the amount of auditory access,
combining number of hours with aided and unaided hearing
during the day) is a protective factor to vulnerable listening
skills. Compliance may be a great problem in mild cases. All
participants in the present study were reported by caregivers
to use their HA on a daily basis, but information on HA
dosage is unfortunately lacking. HL measured as aided au-
dibility of speech and HA dosage are likely to be better pre-
dictors of language skills than the degree of HL.

HAs improve the audibility of speech signals, but even if
children are aided earlier today, there are still a range of
perceptual consequences of HL that HAs cannot fully com-
ensurate for [14,56]. Language learning thus has to take place
with a partial, distorted, and/or degraded signal. Several
studies have shown that HAs result in better language out-
comes even in children with minimal and mild HL [18,21].
This is important knowledge for parents and teachers trying
to motivate children with mild HL to use their HAs. Lofkvist et al. [2] draw similar conclusions regarding even
mild HL being a risk factor for atypical language develop-
ment and the importance of offering services to all families
with children with HL.

Methodological considerations
Apart from what has already been pointed out, our study
has several limitations, which prevent definite conclusions.
Data are from the period before new-born hearing screening
and thus perhaps not representative of today. However, the
recent report [50], as well as communication with research-
ers and clinicians across Sweden, indicate that the situation
with respect to the timing of HAs and intervention has not
changed much. Furthermore, data regarding audibility and
HA fitting and use are largely lacking. For example, the
audibility of the nonwords may have varied individually.
The lack of information on these two factors is a major
methodological concern in this study. It should also be
noted that the NWRep task was purely auditory. This differs
from the situation in most everyday conversations, where
visual cues are also present. Thus, the children may not
have performed according to their potential (cf. the results
in Al-Salim et al. [47]). It would also have been interesting
to include a measure of output phonology to compare to the
performance on NwRep. The studies from which the
present data are taken include output phonology measures
for most of the children. The percent consonants correct on
real words was 90–100%. Thus, output phonology difficul-
ties are not likely to explain the performance on NwRep in
the participants here. There is a need to revise the current
clinical, as well as research protocols, in order to get a grasp
of the relative contribution of different potentially important
factors – hearing, cognitive and contextual. This is import-
ant to be able to deliver accurate diagnosis and individually
adapted services.
Conclusion and implications

Our results indicate that children with mild HL are as linguistically vulnerable as those with moderate HL. Performance on the NwRep task is likely to be more dependent on other hearing factors than the degree of HL, most importantly aided audibility of speech and device use. For example, HA fitting was significantly later in children with mild than in those with moderate HL. SLTs should follow up language development and secure appropriate assessments and services, given the well-known long-term consequences of a HL. There is otherwise a risk for academic failure and poor societal inclusion and participation [46,57].

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Notes on contributors

Birgitta Sahlen is Professor in Speech Pathology at Lund University, Sweden. Her research focus is on cognition and communication in children with language disorder and/or hearing loss. She is heading a comprehensive intervention projects aiming at improving children’s narrative writing, and teachers’ communicative techniques for language learning interaction in the classroom.

Tina Ibertsson has a PhD in Audiology and Lecturer in Audiology at Lund University, Sweden. Her thesis explored the relations between conversation, communication, and cognition in deaf teenagers with cochlear implants. Her research interests are cognition, language and interaction in children and adolescents with different degrees of hearing loss.

Lena Asker-Årnason is a Speech Language Pathologist, former coworker in Lund University with research and teaching, now retired. The subject of her PhD thesis (2011) was narration and reading comprehension in children and adolescents with hearing impairment.

K. Jonas Brännström is an Associate Professor/Senior Lecturer in Audiology at Lund University in Sweden and works at the Audiology and Speech Pathology programs. His research interests include psychoacoustics, cognition, and hearing (including tinnitus), hearing rehabilitation, hearing aid outcomes, and tele-audiology.

Kristina Hansson is Associate Professor in Speech-Language Therapy at Lund University, Sweden. Her research interest is language development and language difficulties in children with developmental language disorder and children with hearing impairment, with special focus on grammar, semantics, and interaction.

ORCID

Birgitta Sahlen http://orcid.org/0000-0002-8468-0546
Jonas Brännström http://orcid.org/0000-0002-3389-5539
Kristina Hansson http://orcid.org/0000-0002-0467-5190

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