Inflectional morphology in German hearing-impaired children

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Abstract
Despite modern hearing aids, children with hearing impairment often have only restricted access to spoken language input during the ‘critical’ years for language acquisition. Specifically, a sensorineural hearing impairment affects the perception of voiceless coronal consonants which realize verbal affixes in German. The aim of this study is to explore if German hearing-impaired children have problems in producing and/or acquiring inflectional suffixes expressed by such phonemes. The findings of two experiments (an elicitation task and a picture-naming task) conducted with a group of hearing-impaired monolingual German children (age 3–4 years) demonstrate that difficulties in perceiving specific phonemes relate to the avoidance of these same sounds in speech production independent of the grammatical function these phonemes have.

Key words: Coronal obstruents, inflectional suffixes, language acquisition, morphology, nasals, phoneme production, phoneme reception, sensorineural hearing impairment, syllable structure, verbal agreement

Introduction
One of the prerequisites of an unimpaired acquisition of spoken language is an intact hearing and thereby an unrestricted language intake. For children with a permanent hearing impairment this is not given despite modern hearing aid technology. There are two hearing devices available for hearing-impaired children: cochlear implants (CI) and hearing aids. A majority of German children with a profound hearing loss receives a CI that replaces the damaged function of the inner ear by transforming acoustic information into neural stimulation. Children with a mild to moderate hearing loss, however, are usually fitted with hearing aids after diagnosis. A hearing aid amplifies the incoming sound and speech signal in the most comfortable range of the child’s hearing (1). Technical limitations related to the quality of amplification in both devices often result in an only partial compensation of the hearing loss. Also, the quality of the auditory perception is very different in both devices. Therefore potential effects of the perceptual limitations on language acquisition in hearing-impaired children have to be investigated independently for children with CI and children equipped with hearing aids. Whereas language acquisition in CI children has been the topic of much research over the last decades (e.g. 2,3), the impact of a restricted auditory input on more moderately hearing-impaired children with hearing aids has only recently come into focus of language acquisition researchers (e.g. 4). Moreover, before the establishment of a system of screening the hearing of newborns a mild to moderate hearing impairment was often only diagnosed during the fourth year of life (5,6). Thus, during the years considered as critical for language acquisition, those children receive a spoken language input deteriorated by the hearing impairment. The aim of this paper is to explore whether such restricted input (or intake) leads to a delay or deficits in the language acquisition of hearing-impaired children that are equipped with hearing aids.
Effects of a sensorineural hearing impairment

Sensorineural hearing deficits particularly affect the perception of speech sounds that fall into higher frequency ranges of 2,000 to 8,000 Hz. Hence, the majority of hearing-impaired children have difficulties to hear high-pitched sounds (7). These problems persist even with modern hearing aids (8). The so-called ‘speech banana’ (Figure 1) illustrates the distribution of speech sounds across the relevant frequency ranges, highlighting the high-pitched sounds [s] and [t] and low-pitched nasal sounds that are of particular relevance for our study. Given the difficulties hearing-impaired (HI) children typically have in perceiving high-pitched sounds (above 2,000 Hz), one would predict that these children experience more problems in perceiving the voiceless obstruents [s] and [t] in comparison to nasals because the former obstruents require an unaffected hearing of higher-frequency ranges in contrast to nasal consonants that fall into lower-frequency ranges, less affected in sensorineural hearing deficits (see Figure 1) (9).

It is well documented that the perception of high-pitched fricatives like [s] is especially difficult for hearing-impaired children and adults (10). There is also evidence that the perceivability of speech sounds has a major impact on the speech discrimination in German children with a moderate hearing impairment. A phoneme discrimination test (the FinKon-Test) shows that German children with a hearing impairment display pronounced difficulties in discriminating a minimal pair such as Fels [fels] ‘rock’ and Feld [fet] ‘field’ when this requires the discrimination between the word-final voiceless obstruents /s/ and /t/. In contrast, discrimination is significantly better when a word-final nasal can be used to disambiguate the final consonant of an auditorily presented word (e.g. Hut [hut] ‘hat’ versus Huhn [hu:n] ‘chicken’). The result is influenced by the degree of hearing loss in higher frequencies, indicating perceivability as a main factor in the discrimination results (11).

Single phonemes such as /s/, /t/, or /n/ can serve to express specific morphosyntactic information, as for instance the 3rd person singular present tense marker –s in English. Like the inflectional marker –s such phonemes might fall into the frequency range affected by hearing impairment (see Figure 1). The unrestricted perception of such grammatically relevant phonemes is likely to be a necessary prerequisite for the acquisition of the morphosyntactic content realized by these phonemes. Although research on the language acquisition of hard-of-hearing children is only in its beginnings, first results indeed indicate that deficits with inflectional morphology occur in young children with sensorineural hearing impairment (4,13–15). The aim of our study is to build up on these findings by specifically targeting the relationship between differences in perceivability for particular phonemes and the acquisition of inflectional affixes that are realized by these very same phonemes. We address this issue by investigating the acquisition of verbal agreement morphology in German hearing-impaired children. Acoustic and morphophonological characteristics of the affixes of the German verbal agreement paradigm (discussed in the next section) suggest that this aspect of grammar might be particularly affected in hearing-impaired children.

**German subject–verb agreement inflection**

German subject–verb agreement inflection marks the morphosyntactic dimensions ‘person’ and ‘number’. For main/thematic verbs, agreement inflection is completely regular in the present tense paradigm. Table I illustrates the agreement paradigm of the different present tense forms of the verb lachen ‘laugh’. The different inflectional suffixes are expressed by three coronal consonants: /s/, /t/, and /n/. In addition, 1st person singular forms are marked by the vowel [ə], an ending that is, however, generally omitted in

| Person       | stem + suffix |
|--------------|---------------|
| 1st singular | lach(-e)      |
| 2nd singular | lach-s(t)     |
| 3rd singular | lach-t        |
| 1st plural   | lach(-e)n     |
| 2nd plural   | lach-t        |
| 3rd plural   | lach(-e)n     |

Figure 1. Distribution of /s/, /t/, and nasals in different frequency ranges.
spoken German where the stem form serves as 1st person singular form (e.g. ich lach instead of ich lache ‘I am laughing’). The 2nd person singular affix –st is often reduced to –s in colloquial spoken German (e.g. du lachs instead of du lachst ‘you are laughing’), and we will therefore refer to this affix with the notation –s(t) in the following. Note, in addition, that the 1st and 3rd person plural ending, although written as –en, is usually reduced to a syllabic sonorant /n/ in articulation (e.g. [laxn̩] instead of [laxən]). We will thus refer to the 3rd person plural suffix as –n.

Most verbal stems in German end in one or two consonants. Inflecting a verb with the suffixes –s(t) or –t hence leads to an accumulation of word-final consonants as the voiceless obstruents that constitute these suffixes are added to the stem-final consonants (e.g. trink + -st → trinkst ‘drink’). German syllable structure allows up to three obstruents to follow the syllable’s nucleus: one in the coda and two in the coronal appendix outside the rhyme (16). In verb forms suffixed with –s(t) or –t, these suffixes appear in the coda or appendix position of the verb stem’s final syllable (see Figure 2A). In contrast, producing a verb form suffixed with –n or –e leads to the addition of a reduced syllable—which encompasses the inflectional affix—to the verb’s stem. This results in a disyllabic foot structure where the suffixes –n or –e occupy the nucleus position of the added reduced syllable as indicated in Figure 2B for the plural verb form lachen ‘laugh’.

Relevant factors regarding the acquisition of agreement morphology in German children with hearing impairment

A number of properties render the investigation of subject–verb agreement inflection in German hearing-impaired children particularly interesting. In contrast to English, German verbal morphology uses both: 1) affixes expressed by the coronal obstruents /s/ and /t/ that fall into the frequency range affected in hearing impairment, and 2) affixes realized by the nasal /n/. Since the perception of nasals is dependent on lower-frequency ranges (see Figure 1) that are, in general, less affected in sensorineural hearing deficits they should be better perceivable. German agreement morphology thus permits to investigate whether the perceivability of speech sounds exerts an influence on the acquisition of a morphosyntactic system in children with hearing impairment because it allows for differentiated predictions as to which affixes should or should not be affected because of the hearing impairment.

Also, a study by Müller-Deile (17) on the speech perception in adult hearing-impaired persons with CI suggests that difficulties in perceiving speech sounds might be especially pronounced for consonants appearing in syllable-final position compared to consonants in syllable-initial position. A hearing impairment that affects the perception of coronal obstruents might hence have a particular impact on the acquisition of the verbal agreement suffixes –s(t) and –t in German hearing-impaired children because these affixes occur in syllable-final positions. In contrast, the suffix –n which occupies the nucleus position of the reduced syllable might be less affected.

Another topic that is of relevance regarding the language acquisition of hearing-impaired children is the sensitive period debate. Investigations on the acquisition of inflectional morphology in child L2 learners have provided evidence for a sensitive or optimal period in which the acquisition of inflectional systems should take place. According to Meisel

![Figure 2. Syllable structure of German verbs.](image-url)
the optimal age for acquiring inflectional systems is likely to begin to fade out as early as between the ages of 3 and 4 years. Given that moderate hearing deficits are often only detected at the end or even after this critical period (5,6), and given that these children do not reach the same quality of hearing with their hearing aids as unimpaired peers, we might expect the domain of inflectional morphology to be especially affected in moderately hearing-impaired children because their received auditory input is deficient during the sensitive period for the acquisition of morphosyntax.

In line with the assumption of a sensitive period, previous research has indicated the importance of an early diagnosis of the hearing impairment for an inconspicuous language development. Several studies have found that the language development of hearing-impaired children that were fitted with hearing aids after their first year of life is more affected compared to children where the hearing deficit is diagnosed and treated within the first months of life (19–21). Note in this respect that in Germany a nation-wide, universal screening of newborns’ hearing was established only in January 2009. This offered the opportunity to explore the effects that the factors ‘age of diagnosis’ and ‘age of treatment’ exert on the acquisition of verbal agreement morphology in German hearing-impaired children.

**Aim of the paper and predictions**

The acoustic and phonological characteristics of the German verbal inflectional system and the assumption of a sensitive period for acquiring this grammatical domain suggest that German hearing-impaired children might experience specific problems in acquiring agreement morphology. Due to the nature of their hearing deficit such children have particular problems in perceiving the voiceless coronal consonants /s/ and /t/. There is a consensus that an ‘inability to perceive the acoustic-phonetic cues of speech affects the child’s ability to articulate the sounds of speech’ (22 p. 768 f.). As a consequence of these perceptual problems, hearing-impaired children might omit or replace voiceless obstruents in their own speech production. Omissions or substitutions of the consonants /s/ and /t/ should involve the agreement affixes that are expressed by these consonants, namely –s(t) and –t. Consequently, we might expect the production of –s(t) and –t-inflected verbal forms to be more affected in hearing-impaired children than the production of verbs inflected with the nasal /n/ whose perception is less affected by the hearing impairment. It is also conceivable that the perceptual problems lead to difficulties in acquiring the morphosyntactic content and function of specific inflectional affixes (such as –s(t) and –t) or affect the acquisition of the agreement paradigm as a whole because contrasting forms in the paradigm cannot be differentiated in perception. If auditory perceptual limitations with specific phonemes such as /s/ or /t/ are at the basis of problems with specific agreement morphemes, we would also expect that such perceptual problems impinge on these phonemes independent of their respective function. Therefore, the production of the phonemes /s/ and /t/ should be affected in those cases where they function as verbal agreement markers as well as in instances where they occupy coda or appendix positions of uninflected words such as Hut ‘hat’, Eis ‘ice’, or Toast ‘toast’. Moreover, if difficulties in perceiving particular obstruents were directly related to problems in using these same phonemes in speech production or to problems in acquiring inflectional affixes expressed by these same obstruents, one might expect a correlation between the degree of hearing impairment and the resulting problems in language production: the more severe the hearing impairment, the more pronounced should its effects be, and the more substitutions or omissions of the relevant phonemes and affixes should be observable. Besides the degree of the hearing impairment, the age at which a child is equipped with a hearing aid might crucially affect the acquisition of the verbal agreement system and the production rate of the critical phonemes. The earlier the intervention took place, the longer is the time span in which a child with hearing impairment received an improved input. Thus we might expect that children that were diagnosed and treated earlier display a better performance with regard to the critical phonemes/affixes than children that were diagnosed and fitted with hearing aids only relatively late in childhood.

The aim of this paper is to address these issues in investigating whether and how the system of verbal agreement inflection is affected in German children with hearing impairment. Specifically, we want to explore if differences in the perceivability of the phonemes /s/, /t/, and /n/ relate to problems in producing and/or acquiring inflectional suffixes expressed by these phonemes and, if so, whether there is a relationship between the degree of hearing impairment and the age of intervention, on the one hand, and the degree with which language is affected, on the other hand. We conducted two experiments with German hearing-impaired children: experiment 1 tested the children’s production of verb forms inflected with the suffixes –s(t), –t, and –n; the second experiment examined the ability to produce the phonemes /s/, /t/, and /n/ in syllabic offset positions of simplex nouns where these phonemes do not have morphosyntactic content but are part of the noun stem.
Methods

Participants

We tested 19 children with a bilateral hearing impairment (HI children) as a result of congenital sensorineural hearing loss. The children were recruited from intervention centers, (pre-)schools for hard-of-hearing children, hearing aid suppliers, medical centers, and pediatric audiologists. The children were 3 to 4 years old when tested (ten aged 3+, nine aged 4+). All children were monolingual German and received no sign-language input. Besides their hearing loss, the children showed no other physical or cognitive impairments. All but two children passed a subscale of a standardized non-verbal intelligence screening (cognitive structures (DS) of SON-R (23)). For two children the scores of the intelligence screening are not available; however, both children displayed no evidence for a cognitive impairment, an impression confirmed by the children’s parents and by reports of the intervention therapists regularly working with these children. The group of HI children achieved an average IQ score of 100 (range 78–120, IQ scores corrected for the Flynn effect (cf. 23)).

The HI children experienced a hearing loss between 32 and 78 dB (unaided) in the better ear. The individual hearing threshold was determined by independent pediatric audiologists or hearing aid audiologists via standard clinical audiometric tests based on pure tone audiometry (PTA). At the time of testing, all children but one had bilateral hearing aids. One child was wearing only one hearing aid as the second was still under repair at the time of testing. Table II summarizes relevant characteristics of the tested children.

As control group, we tested 19 age-matched 3–4-year-old children from monolingual German families (ten aged 3+, nine aged 4+) who had normal hearing (NH) and displayed no evidence for physical or cognitive impairments. The children demonstrated age-appropriate language development according to a standard German screening test (SSV (24)). Intelligence testing with the SON-R intelligence screening resulted in an average score of 106 (range 86–124) for this group. Statistical comparisons revealed no difference between the control group and the group of HI children with respect to age at testing and non-verbal IQ (\( t \) test with Welch’s correction: each \( p > 0.1 \)).

Both groups, HI and NH children, were tested in familiar settings (i.e. at home, in preschool, or in case of the HI children at the therapeutic centers where they regularly received speech therapy). The investigations took place in a quiet room. The children’s parents were asked not to interfere during testing and were usually outside the room.

The research reported in this paper was performed according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the Hamburg Medical Board of Registration. All subjects’ parents gave prior written informed consent to their children participating in the study.

Experiment 1: Description of video scenes—material and procedure

To elicit inflected verb forms, we conducted a production task in which the children were asked to describe the action depicted in 30 short and silently presented video scenes. The videos showed actions that were either performed by a single child, performed by two children unknown to the tested children, or performed by the investigator of the experiment. Scenes, for example, show the experimenter laughing, a child jumping, or two children reading a book. In describing the depicted action, children were expected to produce sentences in three target contexts:

- sentences containing a verb inflected for 2nd person singular as response to videos showing the experimenter in action (e.g. experimenter laughing, expected response: \( \text{du lach}(t) \) ‘you are laughing’),
- sentences with 3rd person singular forms as reaction to actions performed by a single child (e.g. girl jumping, expected response: \( \text{das Mädchen hüpf}t \) ‘the girl is jumping’),

Table II. Characteristics of hearing-impaired (HI) children and children with normal hearing (NH).

| Group | \( n \) | Sex | Mean IQ\(^*\) (range) | Mean age at testing (range) | Mean HL unaided (PTA, dB) (range) | ASFT (dB) | Mean age at onset of HA fitting (range) |
|-------|------|-----|---------------------|--------------------------|-----------------------------------|--------|--------------------------------------|
| HI    | 19   | 11f, 8m | 100 (78–120) | 3 y, 11 mo (3 y, 2 mo – 4 y, 10 mo) | 57 (32–78) | 33 (20–50) | 1 y, 8 mo (3 mo – 4 y, 0 mo) |
| NH    | 19   | 9f, 10m | 106 (86–124) | 3 y, 10 mo (3 y, 0 mo – 5 y, 0 mo) | | | |

ASFT = aided speech field thresholds; HA = hearing aid; HL = hearing level; IQ\(^*\) = value corrected for the Flynn effect; PTA = pure-tone average threshold in the sound field at 0.5, 1, 2, and 4 kHz in decibels.
and sentences with 3rd person plural verb forms induced by actions performed by two children (e.g. two children reading a book, expected response: die Kinder lesen ein Buch ‘the children are reading a book’).

The three chosen contexts require the production of main verbs inflected with one of the verbal suffixes: –s(t) for 2nd person singular, –t for 3rd person singular, and –n for 3rd person plural. For each of these three target contexts we presented 10 videos.

The three grammatical contexts are particularly suited to investigate the acquisition of the agreement paradigm in HI children. By investigating the production of inflected forms in these three contexts we can investigate whether the children under study have acquired the morphosyntactic dimensions of the inflectional paradigm and distinguish 2nd versus 3rd person forms (dimension ‘person’) and 3rd singular from 3rd plural forms (dimension ‘number’). Moreover, as discussed above, the hearing impairment particularly affects the perception of voiceless coronal consonants such as /s/ and /t/, whereas nasals such as /n/ are comparatively better perceived. Hence, if problems in perception influence the acquisition of inflectional affixes, we would expect the acquisition of the 2nd person singular marker –s(t) and the 3rd person singular marker –t to be more affected than the acquisition of the plural marker –n.

The actions depicted in the videos are describable by main verbs that do frequently occur in the input to children (mean verb lemma frequency: 700, according to information in the CELEX database (25)) and are part of the vocabulary of preschool children (based on (26,27)). These target verbs do not require stem changes in the target inflected forms. Moreover, we controlled for the syllable position of the target verbal suffix. Thus, the position of the inflectional affixes (i.e. –st and –t) in the target verb forms for the 2nd and 3rd person singular contexts is balanced between coda and appendix. In half of the target verb forms on –t, the suffix occupies the coda position of the final syllable; in the other half it occupies the appendix. For target verbs inflected with –st, the suffix takes up both appendix positions in half of the items; in the other half of the cases /s/ is in coda position whereas /t/ is in the appendix. The target syllable position for the ten 3rd person plural verb forms is the nucleus (cf. Supplementary Appendix A for more detail to be found online at http://informahealthcare.com/doi/abs/10.3109/14015439.2014.940382).

Videos were presented on a computer screen in front of which child and experimenter sat comfortably side-by-side. The 30 videos were presented in two blocks of 15 trials in a previously randomized order. The test phase was preceded by a short

practice phase with three videos (one for each context) familiarizing the children with the task. Each video took about 10 seconds. After approximately 5 seconds, the experimenter asked the child Was passiert da? ‘what is happening there?’ or Was ist da los? ‘what is going on there?’ to elicit the production of an utterance containing a finite verb. These questions were chosen to discourage the production of non-finite elliptical utterances that are licit for questions such as Was macht das Kind?—Schwimmen ‘what is the child doing?—swimming’. In contrast, an elliptical non-finite utterance is not licit as response to the questions we posed in the experiment. Within the practice phase, the child was introduced to the acting characters (‘Look, here you can see me/a boy/ two children in the picture. Tell me, what’s happening?’) and encouraged to describe the action in a full sentence. Positive feedback was given and the target sentence was provided (‘Yes, you’re right, the girl is crying’). During testing, no target sentence or feedback was provided.

All HI children wore their hearing aids during testing. The experimental sessions were videotaped. The children’s speech was transcribed orthographically by the help of the annotation tool ELAN. Pauses, intonation, and the clear articulation of the critical word-final endings were marked in addition. Pronunciations that deviated from spoken German were transcribed by using IPA. All transcripts were checked against the video files by another experienced researcher. Transcripts were then further evaluated according to the criteria mentioned in the results section.

**Experiment 2: Picture-naming task—material and procedure**

To investigate whether omissions of /s/ and /t/ occur independently of the morphosyntactic content carried by these phonemes, we examined the ability of the HI children to produce the relevant phonemes in syllabic offset positions of simplex nouns where these phonemes do not have morphosyntactic content but are part of the noun stem. We investigated the production of word-final phonemes by conducting a picture-naming task where children had to name an object presented on a colored picture card. To allow for a maximum comparability of the two experiments, the naming task focused on the production of the stem-final voiceless obstruents /s/ and /t/ as opposed to nasal consonants such as /n/ in the cluster /ts/, six nouns ending in /t/ including two words ending in the cluster /st/, and another six
nouns ending in /n/, respectively /m/ in one case. In total, 18 picture cards (plus one practice card) were presented to the children. Because four picture cards involve consonant clusters of the critical phonemes /s/ and /t/, the realization of both phonemes /s/ and /t/ could be tested in these words. Hence, the material provides 22 contexts for the production of the critical phonemes /s/ and /t/ versus /n/ and /m/ in word-final position per child.

All target nouns are monomorphemic simplex nouns that are part of preschool children's vocabulary (26,27) and occur frequently in the target language (mean noun lemma frequency: 211, according to information in the CELEX database (25)). The syllable position of the stem-final phonemes /s/ and /t/ is balanced: in half of the target words the critical consonant (/s/ respectively /t/) is in the coda; in the other half of the target words it takes up the appendix. Half of the target nouns ending in /n/ or /m/ are monosyllabic with the nasal occupying the coda position of the stem's syllable structure (e.g. /hu:/n/ 'chicken'), the other half are disyllabic (e.g. /ku:xn/ 'cake') with the nasal in the nucleus position of a reduced syllable, thus mimicking the disyllabicity of verbal forms in the 3rd person plural (cf. Supplementary Appendix B for more detail to be found online at http://informahealthcare.com/doi/abs/10.3109/14015439.2014.940382).

The naming experiment was run in a separate session which took place shortly after the video task. One of the HI children who completed the video task left the study and did not participate in the naming test any more. Thus, the number of HI children who took part in the naming experiment is 18. During the naming task, the investigator presented the pictures to the child one after another and asked the child to name the object presented. The task was made clear with a practice card for which the target form was provided if necessary. HI children wore their hearing aids during testing. The experimental sessions were videotaped, and the children's speech was transcribed according to the convention stated above. All transcripts were checked by an independent experienced researcher. Subsequently, transcribed reactions were evaluated according to the criteria mentioned in the results section.

**Data analysis**

Based on the reactions provided by our subjects, we computed percentages for each individual subject in each of the critical test conditions. Statistical analyses were performed on these data using parametric statistical tools such as analysis of variance (ANOVA, mixed-design), post hoc t tests, and Pearson’s r correlation tests. Non-normal distributions within the tested groups are accounted for by the use of independent samples t tests with Welch’s correction which adjusts unequal variances between groups (in this case HI versus NH children). In addition, Tables III and IV provide sums of the absolute numbers of the reactions for the two subject groups, NH and HI children, as well as percentages calculated over these summed scores.

**Results**

**Video description experiment**

Children’s utterances in the video description experiment were first categorized as analyzable or unanalyzable with respect to subject–verb agreement. As analyzable utterances we classified reactions which were clearly related to the video scene and which included both a main verb and an overt subject so that correctness or incorrectness of the inflected verb could be evaluated without doubt. In total, we evaluated 570 trials for each of the two subject groups—the 19 HI children and the 19 NH children. Table IIIa shows how these trials divide into analyzable and unanalyzable utterances.

The data display a strong tendency for the 19 HI children to produce fewer analyzable utterances than the 19 control children (t test with Welch’s correction: \( t = -1.737, p = 0.092 \)). Whereas only 74.7% of the utterances produced by the HI children contain an overt subject and a main verb, the corresponding percentage for analyzable utterances produced by NH children is 86.7%. There also is a significant interaction between the three grammatical contexts tested in the videos and the two groups of children (HI versus NH children) (mixed-design analysis of variance (ANOVA), \( F = 3.906, p = 0.025 \)). Post hoc testing revealed that HI children produce a significantly higher number of unanalyzable utterances in 2nd person singular contexts where a verb form inflected with \(-s(t)\) had to be produced compared to NH children (t test with Welch’s correction: \( t = 2.605, p = 0.013 \)). Further differences between HI and NH children show up when different types of unanalyzable utterances are compared. For both subject groups most unanalyzable utterances consist of utterances in which either the subject or the verb is missing. However, whereas the proportion of subjectless sentences is significantly higher for the control group compared to the HI group (t test with Welch’s correction: \( t = -2.502, p = 0.017 \)), HI children, in contrast, produce significantly more utterances in which the verb is missing (e.g. \( \text{'Junge Fahrrad 'boy bike'} \)) than NH children (t test with Welch’s correction: \( t = 2.302, p = 0.034 \)). Both groups produce utterances which do not contain an
### Table III. Results of the video description task.

| Category of unanalyzable forms (% of unanalyzable cases) | 494 (86.7%) | 51 (67.1%) | 151/152 (99.3%) | 180/184 (97.8%) | 61 (42.4%) | 133/133 (100%) | 59/190 (31%) | 31/190 (16.3%) | 21/190 (11%) | 133/145 (91.7%) | 426 (74.7%) | 22 (15.3%) | 24 (16.7%) | 154/154 (100%) | 169/171 (98.8%) | 49/190 (25.8%) | 20 (26.3%) | 180/180 (100%) | 36/190 (18.9%) | 1 (1.3%) | 3 (3.9%) | 1 (1.3%) |
|----------------------------------------------------------|-------------|-------------|-------------------|-------------------|-----------|----------------|-------------|----------------|-------------|-------------------|-------------|-------------|-------------|-------------------|-------------------|-------------|---------------|-------------------|-------------------|-------------|-------------|

The inflection of copula and modal verbs differs from main verbs in German: inflected forms of the copula are highly irregular in German; modal verbs have no overt affix – in the 3rd singular form and display stem changes between singular and plural forms. We therefore excluded utterances containing a copula or a modal verb from further analysis. Note, however, that in all but one instance the inflection of the produced copula or modal verb forms is correct. We furthermore excluded cases in which the grammatical category of the produced words (noun or verb) is ambiguous and cannot be determined from the context (i.e. ‘unclear category’, e.g. *föhn* ‘dry/dryer’ referring to a noun or a verb). Utterances which are not verbal descriptions of the action depicted in the videos were also characterized as unanalyzable (i.e. ‘no related reaction’, e.g. *don’t-know* responses, pantomimic reactions, refusals, or in some instances incomprehensible utterances or babble). The proportion of these non-related reactions is significantly higher for HI children than for control subjects (t test with Welch’s correction: \( t = -4.441, p = 0.000 \)). Summarizing, compared to NH children the HI children produce a higher percentage and a different distribution of unanalyzable utterances. They give more unanalyzable responses in 2nd person singular contexts and display a higher percentage of utterances where the verb is missing or which are not related to the question.

In a second step of data analysis, we categorized whether analyzable utterances display correct or incorrect agreement between subject and verb. In total, 86.9% of the main verbs produced by HI children in analyzable utterances are correctly inflected. The correctness score observed for NH children is 99%. Thus, HI children commit significantly more agreement errors than NH children (t test with Welch’s correction: \( t = -4.149, p = 0.000 \)). A closer analysis of the data reveals that errors are not equally distributed over the three tested conditions: 2nd person singular, 3rd person singular, and 3rd person plural contexts. Table IIIb/c presents the relevant data for the two subject groups. The table gives two types of correctness scores for each of the three tested inflectional markers: 1) a correctness score with respect to the correct realization of an affix in obligatory contexts for this affix (correctness in obligatory contexts, cf. Table IIIb), and 2) a score indicating the correctness of the verbal inflection occurring in a child’s utterance (correct occurrences, cf. Table IIIc).

In determining correctness in obligatory contexts, we proceed from the subject and check whether the verb is inflected in accordance. Consider for example 2nd person singular contexts: 78 of the analyzable
utterances produced by the HI children contain a 2nd person singular subject pronoun *du* ‘you’. These utterances provide an obligatory context for a verb inflected with the 2nd person singular affix –*s*(t). In 68 of these 78 utterances (or obligatory contexts) (= 87.2%) the verb is correctly inflected with the ending –*s*(t) in agreement with the subject. In total, 420 of the 426 analyzable utterances of HI children were analyzed with respect to correctness of marking in obligatory contexts. Six of their analyzable utterances contained subject pronouns that could not unambiguously be classified as 3rd person singular or 3rd person plural subject pronouns (*i.e.* *sie* ‘she/they’) and had hence to be excluded from this analysis.

A first observation regarding the data presented in Table IIIb concerns the distribution of contexts in the two groups of children. The 30 videos provided 10 unambiguous contexts each for utterances containing 2nd person singular, 3rd person singular, and 3rd person plural subjects. Whereas NH children respect these contexts and produce utterances that are about evenly distributed over the three contexts, the distribution of utterances across contexts is markedly skewed for the HI children. Despite the fact that videos presented unambiguous contexts for utterances containing 2nd person singular pronouns, HI children produce fewer such utterances (78 utterances, *i.e.* 18.3% of all analyzable utterances instead of the expected 33%) compared to NH children (151 utterances, *i.e.* 30.6% of all analyzable utterances). This difference is significant (*t* test with Welch’s correction: *t* = -3.574, *p* = 0.001). Instead, HI children tend to generate utterances with 3rd person singular subject pronouns, although the experimenter made sure that the child identified her/himself as actor in the scene (*e.g.* ‘Look, that’s me’). Nevertheless, HI children would then often proceed in describing the action by using a 3rd person singular pronoun (in 40.5% of the 2nd person singular contexts). This observation is in contrast to the NH children who generate about even numbers of utterances with 2nd person singular, 3rd person singular, and 3rd person plural subject pronouns (cf. Table IIIb) and produce 3rd person singular subject pronouns in 2nd person singular contexts in only 10.1% of these contexts—a significant difference (*t* test with Welch’s correction: *t* = 2.930, *p* = 0.007).

Concerning the correctness scores in the three tested obligatory contexts, the data for HI children reveal that the scores for the affixes –*s*(t) and –*t* are significantly lower than the scores for the affix –*n* (paired *t* test: –*s*(t) versus –*n*: *t* = -2.655, *p* = 0.020; –*t* versus –*n*: *t* = -5.000, *p* = 0.000). The correctness scores for –*s*(t) and –*t* do not differ significantly from each other (*t* = -0.376, *p* = 0.713, ns). Whereas HI children apply the required affixes –*s*(t) and –*t* in only 87.2% and 80.9% of the contexts, they perform perfectly when a 3rd person plural form (affix –*n*) is required. In contrast to the HI children who show noticeable differences in correctness scores depending on the different obligatory contexts, NH children display no such differences between the different conditions (paired *t* test comparisons between the different affixes, *p* > 0.19) and achieve correctness scores of over 90% in all three experimental conditions. A comparison of the correctness scores in obligatory contexts for the two subject groups reveals significant differences between HI and NH children with respect to the affixes –*s*(t) and –*t*. For both affixes HI children achieve significantly lower correctness scores (87.2% and 80.9%, respectively) than the control children (100% and 97.8%, respectively) (*t* test with Welch’s correction, –*s*(t) HI versus NH: *t* = -2.655, *p* = 0.020; –*t* HI versus NH: *t* = -3.854, *p* = 0.001). In contrast, correctness scores for the affix –*n* do not differ between HI and NH children, and both groups of children provide the 3rd person plural affix –*n* in 100% of the contexts.

Whereas the affixes –*s*(t) and –*t* are produced with significantly less accuracy in HI children compared to the control group, a different picture emerges when we consider correctness of occurring affixes. This analysis proceeds from the verbal inflection produced and checks whether person and number features of the subject fit the features expressed by the verbal inflection. The corresponding data is presented in Table IIIb. As indicated there, for example, 73 verbs are inflected with the 2nd person singular affix –*s*(t). Of these 73 cases 93.2% are inflected correctly: the utterance contains a 2nd person plural subject pronoun *du* ‘you’ conforming to the inflectional marker on the verb. For the analysis regarding the correctness of occurring affixes, we only included those utterances where the inflected verb carries one of the relevant suffixes (–*s*(t), –*t*, or –*n*). Verbs that are incorrectly inflected with other markers such as –*e* or that are not overtly inflected were not evaluated in this analysis. In total, 37 cases of the analyzable utterances produced by the HI children were therefore excluded from this analysis.

The data displayed in Table IIIb indicate that if a suffix –*s*(t), –*t*, or –*n* is used, it is nearly always applied correctly by HI children: 93.2% of the occurring –*s*(t) suffixes, 98.8% of the –*t* suffixes, and 91.7% of the –*n* suffixes are used correctly by this group of children. Thus, independent of the respective affix high correctness scores are observed. Moreover, these scores are similar to the corresponding correctness values observed for the group of NH children.
Summarizing, the analyses of correctness scores indicate that HI children do not apply the suffixes \(-s(t)\) and \(-t\) in every case where this would be required by the grammatical context. However, when they make use of these affixes they usually apply them correctly.

**Analysis of errors produced by HI children**

In total, HI children produced 56 utterances that display no agreement between subject and verb. The majority of these 56 agreement errors (29 cases, 51.8%) consists of cases where HI children generate verb forms without an overt suffix such as *der Junge kocht* ‘the boy cook’. In the remaining 27 agreement errors, HI children substitute the suffix required by the context either by another overt inflectional marker, albeit not correct in the context, or—in very few cases (3 of 56, 5.4%)—by consonants such as /p/ that do not serve as inflectional markers in German. Replacement by the suffix \(-n\) is the most frequent error type among these substitution errors (12 cases, 21.4% of all errors). In addition to substitutions with \(-n\), five substitutions involve the 1st person singular suffix \(-e\) and another seven cases constitute substitutions with \(-t\) or \(-s(t)\).

The distribution of errors indicates that HI children predominantly produce erroneous forms that lead to a reduction of coda or appendix consonants in stem-final syllables. Most of the errors (50 out of 56) involve cases where verb forms inflected with \(-s(t)\) or \(-t\) are required by the grammatical context. Replacing such forms with either unmarked forms, or in the case of 2nd person singular contexts with \(-t\)-inflected forms, results in a reduction of coda and appendix consonants with respect to the target verb form. Likewise, in errors where the affixes \(-n\) or \(-e\) substitute the correct suffixes \(-s(t)\) or \(-t\), \(-n\) or \(-e\) take up the nucleus position of a new syllable (a reduced syllable) that is added to the syllabic representation of the verb stem (see Figure 2B). The addition of this reduced syllable leads to a process of resyllabification by which syllable-final consonants of the verb stem become syllable-initial consonants of the added syllable (lacht + \(-n\) [la.xn] ‘laugh’). Coda and appendix consonants are thus avoided. Whereas such a reduction of coda and appendix consonants can be observed in 86% of the errors (43 of 50 cases), the reverse, that is an addition of coda and appendix consonants to the stem-final syllable, only occurs in one case where the required suffix \(-t\) is replaced by the suffix \(-st\) (2%). This remarkable difference suggests that syllabic complexity exerts an influence on the observed error types.

**Picture-naming task**

Children’s reactions in the picture-naming task were first categorized as to whether or not they constituted successful attempts to name the object depicted. Failures to name the object or incorrect reactions (e.g. *Katze* [katsa] ‘cat’ instead of the target word *Fuchs* [fokxs] ‘fox’) were not further analyzed. All reactions in which the target noun was either correctly named or mispronounced but clearly recognizable (e.g. [tisn] for [kisn] ‘pillow’) were evaluated with respect to the production of the stem-final phonemes /s/, /t/, /n/, and /m/. Table IV provides an overview of the data.

In total, 87.8% of the NH children’s reactions but only 79.8% of the HI children’s reactions are analyzable, a significant difference between the two groups (t test with Welch’s correction: \(t = -2.085, p = 0.044\). With respect to the analyzable utterances, the control children achieve a mean production score of 98.6%, whereas the HI children produce only 82% of the target phonemes. This difference between HI and NH children is significant (t test with Welch’s correction: \(t = -4.981, p = 0.000\). Table IV, moreover, shows that target phonemes are not
affected equally in the group of HI children: whereas phonemes /s/ and /t/ are not realized in 19.3%, respectively 29.9%, of the target nouns, the phonemes /n/ or /m/, respectively /n/ or /m/, are only affected once. This difference in production scores between the critical phonemes /s/ and /t/, on the one hand, and /n/ or /m/, on the other hand, is highly significant (paired t test: t = −4.931, p = 0.000). In contrast, for NH children production scores for the phonemes /s/ and /t/ on the one hand, and the phonemes /n/ and /m/, on the other hand, do not differ (paired t test: t = −0.769, p = 0.452). The production scores for the critical phonemes /s/ and /t/ differ significantly between both groups of children. Whereas the NH children succeed in producing the critical stem-final phonemes /s/ and /t/ in 98.5% of the cases, the corresponding figure is at only 75.2% for the HI children (production score /s/ HI versus NH: t test with Welch’s correction: t = −3.420, p = 0.003; production score /t/ HI versus NH: t test with Welch’s correction: t = −5.062, p = 0.000). In contrast, HI and control children display no difference with respect to production scores for the phonemes /n/ and /m/ (t test with Welch’s correction: t = 0.089, p = 0.930), where both groups of children obtain production scores at ceiling level (98.9% HI, 99.1% NH).

Table IV also presents an overview on the type of errors observed in the group of HI children for the different target phonemes. Stem-final target phonemes are either omitted or substituted by other phonemes. However, omissions by far outweigh substitution errors and make up 89.5% of the incorrect forms in the HI children’s data (e.g. [keːk] instead of [keːks] ‘cookie’). Moreover, omissions are dependent on the type of stem-final consonant and almost always affect stem-final /s/ and /t/, whereas /n/ and /m/ are only omitted in one case.

The error analysis conducted with respect to the video description experiment (experiment 1) suggests that HI children tend to simplify syllabic complexity in their erroneous forms, preferably by omitting the verbal affixes −s(ʃ) and −t and thereby reducing the number of coda or appendix consonants. To find out whether syllable structure exerts a similar influence on the realization of the stem-final phonemes /s/ and /t/ in the naming task, we evaluated the production of these phonemes in relation to the syllable position (coda or appendix) these phonemes occupy in the respective target words. The experimental material was designed in such a way as to ensure an even distribution with respect to the syllable position the critical consonants /s/ and /t/ occupy in the target nouns. Hence, in 51.3% of the analyzable reactions the critical phonemes /s/ or /t/ were to occupy the coda position of the stem-final syllable, whereas 48.7% of the analyzable reactions involve a consonant /s/ or /t/ in one of the two appendix positions. Despite this balanced distribution, there is a marked imbalance in production scores in the HI children’s data. Whereas HI children produce 82.8% of the target consonants /s/ and /t/ that occupy the stem-final coda position (e.g. [haʊs] and [toʃt]) the corresponding score drops to 60.9% if these critical consonants occupy one of the appendix positions, a significant difference (paired t test: t = 5.271, p = 0.000). In these latter cases, children either omit /s/, /t/, or both (e.g. [kʰut] and [tʊt] instead of target forms [ʃuːf] and [toʃt]) or substitute these phonemes by other phonemes (e.g. [k�ʊt] instead of [kœnts]). The higher vulnerability of /s/ and /t/ in the appendix as opposed to the coda position also holds at an individual level. None of the HI children commits more omissions of the critical phonemes /s/ and /t/ in the structurally less complex coda position compared to the appendix position. The HI children’s difficulty to produce obstruents in appendix position is especially clear in those four nouns that end in the obstruent clusters /st/ or /ts/ (e.g. Toast [toʃt] ‘toast’, Herz [hreʃt] ‘heart’). In these items the second obstruent of the cluster occupies the appendix position. HI children realize these obstruent clusters in only 52% of the cases, whereas in 48% of these cases one or both of the cluster’s obstruents are omitted. In contrast, consonant clusters where the second consonant does not occupy the appendix but the coda position (Hund [hʊnt] ‘dog’) are not reduced but both consonants are always produced by the HI children.

Comparison of results in the two experiments

A direct comparison of the results in the video description task, where the phonemes /s/ and /t/ function as agreement markers, and the picture-naming task, where they do not carry morphosyntactic content, reveals a close correspondence. In both tasks, the phonemes /s/ and /t/ are likely to be avoided, omitted, or substituted by other phonemes. Nasal consonants, in contrast, are reliably produced whether or not they constitute affixes or stem-final consonants. The close correspondence between the two tasks is confirmed by a correlation analysis. The analysis shows a strong positive relationship between the correctness scores (in obligatory contexts) the HI children obtain with respect to the affixes −s(ʃ) and −t in the video description task and the production scores of the stem-final phonemes /s/ and /t/ achieved in the picture-naming task (Pearson’s r correlation test: r = 0.662, p = 0.003).
Impact of hearing level and intervention age on test performance

To investigate whether difficulties in perceiving the high-pitched voiceless coronal consonants /s/ and /t/ are directly related to problems in producing these phonemes in speech, we computed correlational analyses relating the scores the individual HI children obtained in the two experiments to two measures assessing the degree of hearing impairment in these children: 1) degree of hearing impairment as indicated by the hearing threshold measured in dB (unaided hearing level), and 2) degree of hearing obtained by the hearing aid (aided hearing level).

Correlational analyses (Pearson’s r) reveal that there is a significant negative correlation between the (unaided) hearing level (PTA) of the tested HI children and the production score for the critical phonemes /s/ and /t/ in the picture-naming task \((r = -0.479, \ p = 0.044)\). The graver the hearing impairment, the lower are the scores for producing stem-final /s/ and /t/. For the video description task, only a weak correlation between correctness scores in obligatory contexts for the affixes –s(t) and –t and hearing thresholds can be found \((r = -0.350, \ p = 0.142)\). Correlational analyses relating aided hearing level to the scores obtained in the relevant conditions of the two experiments revealed no significant correlations—neither with respect to the video description task \((p = 0.860)\), nor with respect to the naming task \((p = 0.757)\).

The age when the hearing impairment was diagnosed and treated in the children under study here varied between 0.3 and 4.0 years. To address the impact of intervention age on the ability to produce correctly the verbal affixes –s(t) and –t and the stem-final phonemes /s/ and /t/ in the two experiments, we conducted correlational analyses relating for each of the tested HI children their performance in the two experiments to 1) their age at hearing aid fitting, and 2) to the time-span that had elapsed since a hearing aid was fitted (duration of hearing aid exposure in months).

No correlation is found between the experimental results and the age at hearing aid fitting in the group of HI children, neither with respect to the overall accuracy scores, nor with respect to the accuracy scores in the relevant conditions of the two tasks (Pearson’s r correlation test: \(p > 0.1\)). Also, no correlation is found between test results of the video description and the picture-naming task and duration of hearing aid exposure. Again, this holds for the overall accuracy scores as well as for the relevant test conditions in both tasks (Pearson’s r correlation test: \(p > 0.1\)).

Discussion

Congenital sensorineural hearing deficits particularly affect the perception of the voiceless obstruents /s/ and /t/ which fall into higher frequency ranges of the acoustic spectrum and which serve to express person and number information in German verbal morphology. Even a hearing aid cannot completely compensate these perceptual limitations. During the years considered as critical for language acquisition, HI children are therefore exposed to a language input deteriorated by the hearing impairment. The aim of this paper was to explore whether this deficient input leads to impairments of the acquisition of finite verbal morphology—an aspect of grammar that plays a vital role in the acquisition of German (28,29) and that is subject to age effects (18).

Hearing impairment affects German verbal agreement morphology

Data on verbal agreement inflection elicited by a video description task reveal that 3–4-year-old HI children exhibit marked differences to their age-matched hearing peers. For HI children, but not for NH children, the production of correctly inflected finite verb forms is dependent on the type of the required verbal suffix: Whereas the 3rd person plural ending –n is always applied correctly, HI children achieve significantly lower correctness scores (in obligatory contexts) for the inflectional affixes –s(t) and –t. Despite these lower correctness scores, HI children nevertheless apply the affixes –s(t) and –t correctly in over 80% of the obligatory contexts. Also, the finding that the suffixes –s(t) and –t are nearly always correct when used indicates that the HI children have acquired the morphosyntactic content of these suffixes and hence have mastered the German verbal agreement system with respect to its central morphosyntactic dimensions ‘person’ and ‘number’. Thus, although HI children are subjected to a degraded auditory input and are particularly limited in their perception of the voiceless obstruents /s/ and /t/ during the acquisition of the verbal agreement paradigm, they nevertheless succeed in acquiring this system. This finding indicates that language acquisition mechanisms are astoundingly resilient in HI children despite a degraded language input.

Given the evidence that the morphosyntactic content of the verbal suffixes –s(t) and –t is acquired in German HI children, the observation that these suffixes are omitted in about 20% of the obligatory contexts asks for an explanation. Several observations seem relevant in this respect and suggest that HI children display a tendency to avoid verb forms inflected with –s(t) and/or –t: HI children produce
significantly fewer utterances with an inflected verb than NH children, resulting in a higher number of unanalyzable utterances. Also, the distribution of unanalyzable utterances across the three tested grammatical contexts reveals that HI children particularly avoid the production of verbs inflected with \( -s(t) \). They produce significantly more unanalyzable utterances in this context compared to NH children and often avoid the production of an \( -s(t) \)-inflected verb form by producing utterances with a 3rd person singular subject and a \( -t \)-inflected verb instead. This observation is in contrast to the control children who display the lowest percentage of unanalyzable utterances in 2nd person singular contexts and generate an about even number of utterances with 2nd person singular, 3rd person singular, and 3rd person plural subjects as requested by the presented contexts. Finally, the error data indicate that HI children’s errors almost always affect 2nd and 3rd person singular verb forms that are replaced with unmarked verb forms or verb forms inflected with \( -n \) or \( -e \). If errors were due to difficulties in determining the morphosyntactic content of the agreement affixes, errors should likewise have affected the production of 3rd person plural contexts marked with the affix \( -n \). However, the affix \( -n \) was always applied correctly where requested by the obligatory context in HI children.

Summarizing, the data on subject–verb agreement inflection indicate a difference between the affix \( -n \), on the one hand, and the affixes \( -s(t) \) and \( -t \), on the other hand, in HI children. Whereas \( -n \) is applied correctly where necessary, we observe a tendency to avoid, omit, or substitute verb forms inflected with \( -s(t) \) and \( -t \).

**Effects on verbal agreement morphology are dependent on consonant type**

Results of the picture-naming task indicate that the observed tendency in German HI children to avoid, omit, or substitute the word-final consonants /s/ or /t/ holds independently of whether or not these consonants have morphosyntactic content. Thus, HI children also produce significantly fewer instances of /s/ and /t/ in stem-final position of simplex nouns compared to control children, whereas stem-final nasals are reliably produced. This finding suggests that the production of word-final phonemes in German HI children is dependent on consonant type but independent of whether or not these consonants function as agreement markers.

We suggest that acoustic properties of the relevant speech sounds are decisive in this respect. The hearing impairment particularly affects the perception of high-pitched voiceless obstruents such as /s/ and /t/, whereas the perception of nasals is less disturbed. This assumption is supported by results from a phoneme discrimination test (the FinKonTest, (11)) that was conducted with a group of German HI children encompassing the HI children reported in this paper. Test results of this discrimination task indicated that German HI children display pronounced difficulties in discriminating a minimal pair when this requires the discrimination between the word-final voiceless obstruents /s/ and /t/ (e.g. *Fels* [fels] ‘rock’ and *Feld* [flest] ‘field’). Minimal pairs in which a word-final nasal can be used to disambiguate between the members of the pair (e.g. *Hut* [hut] ‘hat’ versus *Huhn* [hun] ‘chicken’) lead to significantly better discrimination rates.3

As to the mechanism relating the difficulties in perceiving the voiceless obstruents /s/ and /t/ and the tendency to avoid these obstruents in speech production, we can only speculate. It seems conceivable that problems in perceiving /s/ and /t/ in the degraded speech signal also affect the proprioception of these obstruents in HI children’s articulations and result in uncertainties regarding the articulatory control of these speech sounds. These insecurities might lead HI children to avoid these critical speech sounds in their own speech production.

The findings of our study find support in previous research on English-speaking HI children. Norbury et al. (4) elicited past and present tense verb forms in 19 school children with mild to moderate hearing impairment and also tested the ability to discriminate between word pairs differing by the phonemes /s/ and /t/ (e.g. ‘guess’ and ‘get’). They report that, as a group, HI children acquired an appropriate knowledge of finite verbal morphology. Nevertheless, they displayed some problems in providing finite verb forms, problems that were particularly pronounced for a group of younger HI children and that were related to the phonological complexity of the verb stem: correctness scores decreased when the verb stem ended in a consonant cluster. Also, discrimination was significantly impaired in the HI children, and discrimination scores displayed a positive correlation with scores for finiteness marking on verbs. The results of Norbury et al. concur with recent findings of Moeller et al. (15) who tested the language outcomes of four children with late-identified hearing impairment in a longitudinal study (ages 2–3 years until 7 years). Analyzing spontaneous speech samples, they observed that HI children were delayed in their development of the 3rd person singular marker –s compared to age-matched hearing peers and suggest that limitations in the audibility of fricative sounds especially in cases where these fricatives are blended with a preceding plosive (e.g. ‘wants’) might have contributed to the...
observed delay. In a training study with older hard-of-hearing children Bow et al. (31) found that a phonological training including sounds like /s/ or /t/ improved not only speech perception scores but also the ability to decide if a noun or verb form was correctly inflected or not. This result supports our suggestion that impairments in producing correctly inflected finite verb forms in HI children are indeed based in difficulties to perceive the relevant speech sounds. Moreover, Bow and colleagues’ study suggests that such perceptual problems can be ameliorated by specifically devised training programs. A connection between the acoustic properties of morphological markers and their production rate in hearing-impaired children is also made in a study by Svirsky et al. (32) conducted with cochlear-implanted children. Svirsky et al. formulate the so-called ‘perceptual prominence’ hypothesis: the less perceptually prominent inflectional markers are, the more difficulties children will have to acquire such markers. The findings by Svirsky et al. can, however, not be directly transferred to HI children without a CI, as perceptual problems differ in both groups. In sum, these studies provide evidence for a relationship between difficulties in perceiving speech sounds and the success in producing these phonemes in verbal inflections, thus confirming a central finding of our study.

Effects of syllable structure

An analysis of the incorrectly inflected verb forms in the video description experiment revealed that errors selectively affect 2nd and 3rd person singular verb forms in German HI children. These verb forms are replaced with unmarked verb forms or verb forms inflected with –n or –ɛ. The affixation of –s(t) and –t enhances the complexity of the stem-final syllable by adding coda and appendix consonants. Replacing –s(t)-inflected forms by –t-inflected forms or replacing both –s(t)- and –t-inflected verb forms by unmarked forms or forms inflected with –n and –ɛ reduces the complexity of the stem-final syllable by reducing the number of syllable-final consonants. Substitutions with –n or –ɛ result in the addition of a reduced syllable that is added to the syllabic representation of the verb stem and contains the suffix in its nucleus (see Figure 2B). The addition of a reduced syllable nevertheless reduces the complexity of the syllabic structure of the resulting verb form. Via a process of resyllabification syllable-final consonants of the verb stem become syllable-initial consonants of the added syllable (lach + –n [la.xn] ‘laugh’) in these cases, thus avoiding the production of coda and appendix consonants. Syllables without coda and appendix are considered to be structurally less complex or unmarked in phonological theory (33 p. 92 ff.). This follows from typological considerations and from the observation that codas are frequently avoided as a result of phonological processes. Also, investigations on the acquisition of syllable structure in German have provided evidence that acquisition proceeds from simple CV syllables to syllables including obstruents in coda and finally appendix position (34). The error data thus point to differences between –s(t)- and –t-inflected forms, on the one hand, and –n-inflected forms, on the other hand, that relate to the complexity of syllable structures of these inflected forms.

A closer investigation of the syllable structure of the nouns named by HI children in the picture-naming task confirms the assumption that their performance is not only dependent on the type of word-final consonant (/s/ or /t/ versus nasals) but that the likelihood to produce the obstruents /s/ and /t/ decreases with increasing complexity of the syllabic offset of a word. The /s/ and /t/ are especially prone to be omitted or substituted when they occupy the syllable’s appendix. This is particularly clear for those four nouns that end in in the obstruent clusters /st/ or /ts/ (e.g. Toast [toːst] ‘toast’, Herz [hɛʁts] ‘heart’) and where both obstruents were only realized in 52% of the cases. Note that the observed tendency to omit /s/ and /t/ from the syllabic appendix position cannot simply be attributed to a tendency to reduce consonant clusters in syllable-final position. Whereas obstruent clusters where the second obstruent occupies the appendix are omitted or reduced frequently, consonant clusters where the second consonant does not occupy the appendix but the coda position are not reduced or omitted. This observation suggests that the omission of syllable-final obstruents is related to the syllable position these obstruents occupy rather than to a strategy to reduce consonant clusters.

Both factors, consonant type and syllable complexity, interact. Thus, the production of –n-inflected 3rd person plural forms is unaffected in German HI children because this person/number marking is expressed by a nasal, a low-pitched sound whose perception is less affected by the hearing deficit, and because the –n suffix occupies the nucleus position of a reduced syllable that is added by the affixation. Subsequent processes of resyllabification bring about that stem-final consonants are realized in the onset position of this reduced syllable, thus reducing the complexity of the verb stem’s syllable structure (see Figure 2B). In contrast, the suffixes –s(t) and –t are not only more difficult to perceive for HI children but they also add to the phonological complexity of the verb’s syllable structure because their affixation leads to an accumulation of stem-final consonants in coda and appendix positions.
**Impact of hearing level**

With respect to the impact of hearing level on the HI children’s performance, the findings suggest that there is a more direct relationship between the perception of /s/ and /t/ and their production as stem-final phonemes compared to the production of these phonemes when they carry grammatical function and serve as agreement markers. Other studies on the language acquisition of HI children have also failed to find a correlation between unaided hearing level and performance in morphosyntactic tests (e.g. 13,21), suggesting that the relationship between unaided hearing level and grammatical achievements is not a direct one but that additional factors come into play that influence the HI children’s behavior besides hearing level. Such factors might include quality and frequency of input, phonological memory and phonological processing capacities, auditory feedback, and the quality of amplified hearing, which might not be sufficiently measured in terms of aided hearing level. Note in this regard that the correlational analyses relating aided hearing level to the scores obtained in the picture-naming and the video description test do not yield significant effects, thus supporting critical views on the role of the aided sound field threshold (or the so-called ‘functional gain’) as a valid variable in clinical work (35).

**Impact of age of intervention**

With respect to the influence of age of intervention, data analyses indicate that the age at which the hearing impairment was diagnosed and a hearing aid was fitted does not influence the performance of the HI children in the subject–verb agreement or the picture-naming task. The lack of an effect of the factor ‘age of intervention’ is in contrast to other findings on language abilities in HI children (e.g. 20,21). Whereas these studies included children with severe hearing impairment, our study focused on children with more moderate deficits. Other studies with moderately hearing-impaired children also failed to detect an impact of age of hearing aid supply (4). It is thus conceivable that effects of an early diagnosis might be more pronounced in severely hearing-impaired and deaf children than in moderately affected children. Moreover, a counteracting factor might have blurred the influence of intervention age in our data. HI children that are diagnosed and treated relatively late in childhood evidently display a less conspicuous language development—otherwise their hearing impairment would probably have been diagnosed earlier. The benefit an early diagnosis offers for language development might hence be obscured by comparing early diagnosed children with children that—although identified later—display a relatively inconspicuous language development. Potential differences in performance between early and later diagnosed children might thus have been minimized. More data are needed to resolve the issue whether age of intervention does or does not affect language performance in these children.

**Delay or deficit?**

The data on subject–verb agreement inflection elicited by the video description task show that 3–4-year-old HI children exhibit marked differences to their age-matched hearing peers in providing –s(t)- and –t-inflected verb forms in 2nd and 3rd person singular contexts. Whereas HI children display a strong tendency to avoid, omit, or substitute verb forms inflected with –s(t) and –t, the 3rd person plural ending –n is always applied correctly. An open issue with respect to these findings is whether the observed difference between NH and HI children has to be characterized as a developmental deficit, i.e. a development that is atypical in comparison to NH children, or whether it indicates a protracted but normal language development that leads to a delay in the acquisition of verbal agreement markers in comparison to NH children. The usually applied criterion to distinguish a deficit from a delay is whether or not the observed language behavior corresponds to an earlier acquisitional stage of typically developing children. If it does, the observed difference is categorized as a developmental delay. However, if the observed behavior does not correspond to behavior observed in typical development, the difference is categorized as a deficit. Given this classification the observed difference between NH and HI children with respect to the production of agreement markers cannot be characterized as a developmental delay since the observed data are in clear contrast to the developmental sequence typically observed in the acquisition of agreement morphology in NH German children (cf. 28,36 p. 174–9) where the 2nd person singular marker –s(t) is acquired before the 3rd person singular marker –t which is acquired before the plural marker –n. An inflectional marker is acquired when the child has uncovered the grammatical features the inflectional ending marks. Then, s/he will be able to use this marker correctly with respect to the target language. According to a standard criterion often employed in acquisition research this point is reached when the respective inflectional marker is used correctly in over 90% of the obligatory contexts for this marker (cf. 37). Adopting this criterion, research on the
acquisition of German verbal agreement markers (28, 36 p. 174–9) has shown that the suffix –s(t) is typically the first suffix whose morphosyntactic content (i.e. [+ 2nd person]) is identified by German children. In contrast, –n is among the first affixes to be used by German children, but its morphosyntactic properties (i.e. [+ plural]) are acquired only relatively late, after person distinctions have been established in the singular. The developmental sequence –s(t) before –t before the plural marker –n is grounded in inherent properties of the German system of verbal inflection which further the early acquisition of the affix –s(t) (36). The affix –s(t) occurs frequently in child-directed speech, it is phonologically ‘heavy’, being the only verbal affix that consists of a consonant cluster, and it is the only verbal affix that expresses only one morphosyntactic feature combination, namely 2nd person singular. In contrast, the affix –n serves to express different morphosyntactic features such as 1st and 3rd person plural, the infinitive, the past participle of strong verbs, and it furthermore serves as inflectional marker in nominal paradigms as well. The finding that HI children display difficulties in providing the affixes –s(t) and –t but show no problems with the plural marker –n does, hence, not correspond to any stage in the typical development of verbal agreement markings.

Classifying the difference between HI and NH children as a deficit in language development is, however, also problematic since it is unclear what such a developmental deficit in HI children would precisely consist of. Although the observed differences between HI and TD children with respect to –s(t) and –t inflection in obligatory contexts for these suffixes indicate a certain propensity to omit or replace these affixes, the observed high correctness scores (over 90% with respect to correct occurrences of affixes, over 80% in obligatory contexts) suggest that the grammatical module of HI children is robust and gains enough relevant information from the impaired perception of these phonemes nevertheless to acquire the agreement system. We therefore conclude that the grammatical knowledge underlying the production of the inflectional markers has been acquired by HI children and is not deficient compared to the NH children. It is only the likelihood to produce inflected verb forms that is affected by phonetic/phonological properties of the different phonemes in HI children but not NH children. While the attained end-state in grammatical knowledge is similar in HI and NH children, the developmental path chosen by HI children in the acquisition of the verbal agreement system might be different from the development observed in NH children. Our data, however, do not allow us to address this issue that requires a detailed investigation of longitudinal data and has to be left to future research.

Summarizing, the data of our study show that German HI children display specific problems in producing finite verb forms although these children have acquired the morphosyntactic content of the relevant inflectional affixes. Our study is the first to demonstrate that the likeliness to avoid the production of an inflectional ending is closely tied to the acoustic properties of the phonemes that express the inflectional affixes and to the syllable structure the critical speech sounds are to occupy. However, the limited perception of moderately affected HI children does not impede the acquisition of an inflectional system where such speech sounds are used to express grammatical information. Our study thus provides an example of the remarkable resilience of language acquisition in the face of degraded input.

Notes

1. A reviewer of this paper suggested that the difficulties in discriminating the phonemes /s/ and /t/ in the above-mentioned FinKon discrimination task might also be due to a closer acoustic distance between the two phones [s] and [t] as opposed to the nasal [n]. A recently proposed metric of phonetic similarity by Mielke (12) provides, however, no empirical evidence for the claim that the obstruents [s] and [t] are considerably closer with respect to acoustic distance than [s] versus [n] or [t] versus [n]. Given this metric, it seems unlikely that the results observed in the FinKon discrimination test could be due to differences in the acoustic distance between the critical speech sounds. As the reviewer comments, Mielke’s findings do not preclude that with respect to perceptual confusions between the three critical consonants [s], [t], and [n] the last-mentioned consonant might be less confusable in perception than the two first-mentioned consonants even in adult subjects with unimpaired hearing. To our knowledge, however, no such evidence is available for German.

2. We adopt here an analysis of German syllable structure by Grijzenhout (16) who proposes that the nucleus is bipositional and may be occupied by a long vowel, or a short vowel plus a sonorant (i.e. a glide, a liquid, or a nasal). Segments in the nucleus may be followed by a less sonorant consonant in the coda position of a rhyme. Obstruents never occupy a nucleus position but the coda or appendix position.

3. A reviewer of this paper suggested that the observed differences of HI children in producing
the word final obstruents /s/ and /t/, on the one hand, and nasals, on the other hand, might be related to differences in the acquisition of these phonemes. Whereas nasals are among the earliest sounds in babies' inventories, especially /s/ is one of the last speech sounds to be acquired by German children (30). Hence, the avoidance of /s/ and /t/ might be related to the fact that the HI children have not acquired these sounds yet. Two points argue against this suggestion, however. Firstly, all of the tested HI children were well able to produce the phonemes /s/ and /t/ in word final position. Secondly, although the phoneme /s/ is acquired relatively late by German children, difficulties in acquiring this phoneme relate to its place of articulation, with many children producing an interdental [θ] instead of the alveolar [s]. Since this pronunciation is very common among German children well into school age (30 p. 62–5), we judged such productions of the phoneme /s/ as correct. Note also, that [θ] and [s] are similar in pitch and require perception of a similar frequency range according to the speech banana.

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Supplementary material available online

Supplementary Appendix A and B.