THE ACQUISITION OF VERBAL MORPHOLOGY IN GERMAN CHILDREN WITH HEARING IMPAIRMENT - A COMPARISON BETWEEN CHILDREN TREATED WITH HEARING-AIDS AND CHILDREN WITH CI

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ABSTRACT

To acquire German verbal agreement-morphology, the relevant inflectional affixes (–st, –t, and –n) have to be perceived and produced. The paper explores the relationship between the discrimination and production of the phonemes /s/, /t/, and /n/ in 3 tasks: (i) a discrimination task (Huhn ‘chicken’ vs. Hut ‘hat’), (ii) a production task (pronounce Hut ‘hat’ in a picture naming task), and (iii) an elicitation task exploring the use of these phonemes as inflectional morphemes (er geht ‘he is walking’).

Here we want to explore whether HI children treated with a hearing-aid display a different behavior with respect to the use and correctness of verbal agreement markers than HI children treated with a CI.

For the 3 tests mentioned above, we compared the performance of two groups of 4-year-old monolingual German HI children: a group of 10 children treated with hearing-aids and a group of 10 children treated with CI.

Despite differences in treatment (hearing-aid vs. CI) and consequently in the acoustic perception of speech, HI children in both groups displayed similarities in their language performance with respect to overall performance in the three tests. Detailed analyses, however, revealed different performance patterns between the two subject groups that relate to differences in the perception and production of the critical phonemes (/s/, /t/, /n/).

INTRODUCTION

Access to auditory language input constitutes the essential condition for oral language development. Therefore, in hearing-impaired (HI) children an early treatment of the hearing impairment is vital to avoid negative long-term effects on speech and language development as well as on educational outcomes. Hearing aids (HA) and Cochlear Implants (CI) are the most common hearing devices. They differ fundamentally in their technical procedure and consequently in the hearing impression they provide.

A HA amplifies the incoming sound and speech signal in the most comfortable range of the individual’s hearing. High pitches, however, offer challenges to the amplification (Friedrich, Bigenzahn & Zorowka 2013). Despite different techniques to compensate for the impaired perception of high-pitched sounds (such as /s/ and /t/) that is characteristic in sensorineural HI (Pittman & Stelmachowicz 2003), investigations in clinical settings show a persistent problem of high-pitched sound perception for HA users, especially if these sounds appear at the end of words (Hennies et al. 2012; Ching et al. 2013; Bentler et al. 2014). A CI replaces the damaged function of the inner ear by transforming acoustic information into neural stimulation (Elloy & Marshall 2012). In contrast to HA, CI do not leave any gaps in the total frequency bandwidth required for speech perception since modern amplifications are able to stimulate frequencies between 200 and 8500 Hz (Riss et al. 2011). Nevertheless, children using a CI have difficulties in perceiving unstressed elements such as suffixes and word-final consonants (Svirsky et al. 2002).

Differences in the quality of the auditory signal provided by HA and CI are likely to affect language acquisition differentially, leading to distinct and characteristic difficulties. So far, however, only few studies have addressed differences in language development between HI children equipped with HA and HI children treated with CI (e.g. Baudonck et al. 2010). The aim of our study is to contribute to this issue by investigating whether German sensorineural
HI children with HA and children with CI differ with respect to the production of verbal agreement affixes that are expressed by high-pitched and low-pitched consonants.

German verbal agreement inflection marks the morphosyntactic information PERSON and NUMBER by inflectional suffixes attached to the verb's stem. Here, we will focus on the 2nd singular marker –st, the 3rd singular marker –t, and the 3rd plural marker –n. The phonemes /s/ and /t/ which express the suffixes –st and –t are high pitched sounds which are difficult to perceive for sensorineural HI children who use HA. The nasal /n/ representing the 3rd plural marker –n is, however, low-pitched and thus better perceivable for children with a sensorineural HI treated with a HA.

A recent study by Penke et al. (2014) found that in 3-to-4-year old German HI children supplied with HA the production of verbal agreement markers was dependent on the type of the required verbal suffix: whereas the 3rd plural ending -n was always applied correctly, HI children avoided the production of verb forms inflected with –st and –t, obtaining significantly lower accuracy scores for these two affixes compared to a group of age-matched children with unimpaired hearing. This study provided evidence for the assumption that auditory perceptual limitations with high-pitched phonemes such as /s/ or /t/ affect the production of verbal agreement markers that are realized by these very same phonemes in HI children supplied with HA.

The production of verbal agreement markers in German HI children supplied with CI has not yet been investigated to our knowledge. A recent study on Dutch children found that only 60% of the tested 4-year-old HI children with CI showed age-appropriate accuracy rates for verbal agreement inflection (Hammer et al. 2014), thus suggesting that this aspect of grammar also provides an area of difficulty for HI children with CI. However, the different techniques employed in HA and CI and the different acoustic impressions resulting from these techniques make it likely that impairments in verbal agreement morphology differ between children supplied with HA and children carrying CI. Specifically, the selective vulnerability of the verbal agreement markers –st and –t found in German HI children with HA by Penke et al. (2014) should not be observed in children equipped with CI, since CI stimulate frequencies between 200 and 8500 Hz and do not lead to specific deficits in perceiving high-pitched consonants (Riss et al. 2011).

The present study compares the production of the German verbal agreement markers –st, –t, and –n in 4-year-old children with bilateral sensorineural HI fitted with HA and with CI. We will target the issue whether the two different types of hearing device differentially affect the ability to perceive and produce the high-pitched and low-pitched word-final consonants that function as verbal agreement markers in German.

**METHOD**

**Design and Participants**

We investigated two groups of children: nine children fitted with bilateral HA and ten children fitted with bilateral CI. All participants show a bilateral sensorineural hearing impairment and were 4 years old (mean age 4;6). The children were monolingual German and oral communicators. None of the children suffered from additional physical or mental deficits. Children equipped with CI (5 boys, 5 girls) received bilateral CI before their second birthday, i.e. on average 3;8 years before testing. Their average aided hearing loss was 29 dB. The group of children wearing HA consisted of three boys and six girls with an average aided hearing loss of 34 dB and an average hearing age of 2;6 years. All children wore their hearing aids during testing.

**Materials and procedures**

We conducted three experiments on (i) the production of verbal agreement markers as well as (ii) on the production and (iii) perception of word-final consonants.

(i) In experiment 1, children were asked to describe the action depicted in 30 short and silently presented video scenes. Actions were either performed by a single child, performed by two children unknown to the tested children, or performed by the investigator of the experiment. In describing the action, children were expected to produce sentences
containing:
- a verb inflected for 2nd singular as response to videos showing the experimenter in action (e.g. experimenter laughing, expected response *du lachst* ‘you are laughing’),
- a 3rd singular verb form as reaction to actions performed by a single child (e.g. girl jumping, expected response *das Mädchen hüpf* ‘the girl is jumping’),
- or a 3rd plural verb form 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’).

For each of these three target contexts 10 videos were presented.

(ii) Experiment 2 tested the ability to produce the phonemes /s/, /t/, and /n/ - that are used as verbal agreement markers - in word-final positions of simplex nouns where these phonemes do not have morphosyntactic content but are part of the noun stem (e.g. *Hut* ‘hat’, *Eis* ‘ice’, or *Toast* ‘toast’). Children were asked to name an object presented on a colored picture card. 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.

(iii) Experiment 3 – a picture-word-matching task - tested the ability to discriminate the critical phonemes /s/, /t/, and /n/ in word-final position in speech perception. Children were presented with a triplet of pictures – two pictures depicting a phonological minimal pair (e.g. a hen *Huhn* [hu:n] and a hat *Hut* [hu:t]) and one showing a phonologically unrelated distractor (e.g. a house *Haus* [haus]). Children were asked to point to the picture of the triplet that matched the word they heard over loudspeakers. The test list consisted of 11 minimal or near minimal pairs (22 nouns).

More information on the three experiments can be obtained from Penke et al. (2014) and Hennies et al. (2012).

**RESULTS**

**Experiment 1**

Accuracy of the verbal agreement marker supplied was evaluated for all utterances that contained a subject and a main verb so that correctness or incorrectness of the subject-verb agreement inflection on the verb could be evaluated without doubt. In total, the children fitted with CI obtained an average accuracy score of 88.1% (SD 18.94). This score does not differ significantly from the mean accuracy score of 90.6% (SD 9.26) observed for children fitted with HA (*Mann-Whitney-U-Test*, *p* = .482) (cf. figure 1). In addition to the overall accuracy scores, we computed accuracy scores for each individual subject in each of the three test conditions, i.e. 2nd and 3rd singular and 3rd plural (cf. figure 1). A statistical comparison of the accuracy scores obtained in the three tested contexts yielded a significant difference for children wearing HA (*Friedman*, *p* = .001) but not for children with CI (*Friedman*, *p* = .395). Children with HA obtained significantly higher accuracy scores for the 3rd plural marker –*n* compared to the 2nd and 3rd singular markers –*st* and –*t* (*Wilcoxon*, *p* = .016).
Experiment 2
All reactions in which the target noun was produced were evaluated with respect to the production of the stem-final phonemes /s/, /t/, /n/, and /m/. Children fitted with CI realised the final consonants of the target-items in 91.8% of the cases, whereas children fitted with HA realised 88.9% of the target consonants (cf. figure 2). This difference is not significant (Mann-Whitney-U-Test, \( p = .170 \)). A comparison of the production rates for the word-final high-pitched consonants /s/ and /t/ on the one hand and the production rates for the low-pitched consonants /n/ and /m/ on the other hand yielded a difference between the two subject groups. While for children wearing HA production scores for word-final low-pitched consonants were significantly higher compared to production scores for word-final high-pitched consonants (Wilcoxon-Test, \( p = .016 \)), no such difference could be observed for the group of children wearing CI (Wilcoxon-Test, \( p = .125 \)).

Experiment 3
All reactions where the child unambiguously pointed to one picture of the triplet in response to the stimulus were evaluated. On average, the sample of children fitted with CI pointed to the correct picture in 76% (SD 14.7) of the cases, whereas children fitted with HA responded correctly in 69% of their responses on average. The difference in accuracy scores between
the two subject groups is not significant (Mann-Whitney-U-Test, \( p = .315 \)). A similar performance between the two groups can also be observed with respect to their incorrect reactions. The phonologically similar picture was chosen in 22\% of the cases by children fitted with CI and in 27\% of the cases by children fitted with HA (Mann-Whitney-U-Test, \( p = .661 \)). The unrelated distractor was chosen in 2\% of the cases by children fitted with CI and in 7\% of the cases by children fitted with HA (Mann-Whitney-U-Test, \( p = .243 \)) (cf. figure 3). These finding indicate that the HI children were not able to reliably discriminate between the tested word-final consonants.

**DISCUSSION**

With respect to the overall scores obtained in the three reported experiments the two groups of HI children did not differ from each other.

In the production tasks (experiments 1 and 2), both groups of children achieve scores of about 90\%. These overall high scores indicate that despite their initially more severe HI, early bilaterally implanted children catch up with the less affected children fitted with HA before their 5\textsuperscript{th} birthday.

Nevertheless, the accuracy and production scores achieved by both groups of HI children are considerably lower than the performance that can be expected from children with unimpaired hearing. Typically developing children between 3-to-4 years of age have been observed to achieve an average accuracy score of 99\% in experiment 1 and a production score of 98.6\% in experiment 2 (cf. Penke et al. 2014). For a group of 4 year old hearing children Hennies et al (2012) report an accuracy score for experiment 3 of 95\%. The difference observed between HI children and children with unimpaired hearing suggests that the input HI children receive during language acquisition is deficient and affects the production and the perception of word-final phonemes, independent of the particular hearing device chosen.

Importantly, both groups of HI children achieve similar scores in experiment 1 where the produced word-final consonants serve as verbal agreement markers and in experiment 2 where these word-final consonants do not have morphosyntactic content but are stem-final phonemes. This observation suggests that the production of word-final phonemes in German HI children is independent of whether or not these consonants function as agreement markers. HI children, thus, display no evidence for a morphosyntactic problem affecting the choice of the correct agreement marker, but their difficulties in producing word-final
consonants (suffixes or stem-final consonants) in both experiments seem to be based on the acoustic properties of the relevant speech sounds that affect their perception in HI children. This assumption is supported by the results of experiment 3 which clearly show the difficulties HI children experience in reliably discriminating the tested word-final consonants.

Despite the similarities in overall accuracy scores obtained in the three experiments, more detailed analyses revealed an interesting difference between the two subject groups. For HI children treated with HA performance with respect to the production of word-final consonants was dependent on consonant type in experiment 1 and 2. Production of the high-pitched word-final consonants /s/ and /t/ was less successful than the production of low-pitched word-final nasals. For children with CI, in contrast, no such difference could be observed. The difference between the two subject groups is likely to relate to the different types of amplification used in HA and CI. Whereas the perception of high-pitched consonants is often defective in HA users, a similar problem does not occur in users of CI. The differences observed in the performance patterns of the two subject groups hence provide evidence for the assumption that the different techniques employed in HA and CI and the different acoustic impressions resulting from these techniques differentially affect language acquisition in HI children supplied with HA and HI children treated with CI.

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