STANDARDIZING THE NEW SPEECH AUDIOMETRIC FINKON-TEST

Johannes Hennies[1], Eva Wimmer[2], Martina Penke[2], Markus Hess[3] and Monika Rothweiler[4]
[1]University of Education Heidelberg, Germany
[2]University of Cologne, Germany
[3]University Medical Center Hamburg-Eppendorf, Germany
[4]University of Bremen, Germany

ABSTRACT

The paper presents data from an ongoing standardization of a new speech audiometric test for hearing impaired children. The test focuses on the ability of children to discriminate phonemes that are important for German verb morphology, i.e. /s/, /t/ and /n/ in the word- and syllable-final position (syllable offset or reduced last syllable). A pilot study showed that three- and four-year-old hearing impaired children with hearing aids (HA) have specific problems with the discrimination of these phonemes (Hennies et al. 2012). Since German speech audiometric tests do not test the ability to differentiate between phonemes in word- and syllable-final positions so far, this new test has been adapted for clinical audiometric setting (Stropahl & Hennies 2011) and there is an ongoing data collection in order to establish group specific age norms. A sample of 63 typically developing hearing children (TD), 72 children with HA, and 32 children with CI (hearing impaired with cochlear-implants) at the age of 3 to 10 has been collected (as of February 2015). Preliminary results indicate that TD-children still develop their phonological system until the age of four, when they reach a correctness score of 90%. Children with HA show a continuous improvement and reach a similar correctness score at the age of seven. Children with CI show lower results with a smaller gain over the years.

INTRODUCTION

For the acquisition of German subject-verb-agreement-morphology children need to realize the function of the coronal consonants /s/, /t/, and /n/ which function as person and number suffixes for 2nd sg (-st), 3rd sg / 2nd pl (-t), and 1st and 3rd pl (-en) in the present tense (e.g. 3rd person singular: er geht ‘he goes / he is going’; 2nd person singular: du gehst ‘you go / you are going’; 1st person plural: wir gehen ‘we go / we are going’). These consonants also appear in complex syllabic offset positions, because in German syllable structure up to three obstruents can follow the syllable’s nucleus; one in the coda and two in the coronal appendix outside the rhyme (Grijzenhout 2001; Vennemann 1988; e.g. 2nd person singular: du lachst ‘you laugh / you are laughing’, where /s/ is in first-appendix-position and /t/ in second-appendix-position). Therefore the perception of coronal consonants is one of the central prerequisite for the acquisition of inflectional suffixes in German. Of these suffixes /s/ and /t/ are especially difficult to perceive because they are high-pitched and voiceless phonemes. Since most of the children with a sensorineural hearing loss have a sloping hearing threshold (Pittman & Stelmachowicz 2003, 200f), they usually have specific problems to perceive sounds in hear high frequencies. This could lead to problems in the acquisition or the use of German verb morphology in children with hearing impairment, because they might not able to identify the relevant suffixes (Penke et al. 2014). However, none of the existing German speech audiometric tests for children focuses on the ability to discriminate these coronal consonants in the word- or syllable-final position.

PURPOSE

In order to provide a diagnostic tool to test children’s abilities to discriminate phonemes that are important for German verb morphology, a new speech audiometric test – named *FinKon-test (Finale-Konsonanten-Test* – ‘final consonants test’) – has been developed and tested in a pilot version as part of a psycholinguistic research project on grammatical acquisition in hearing impaired children (Hennies et al. 2012, Penke et al. 2014). The pilot study showed that children with HA have problems to discriminate these phonemes: The three and four year old children with HA reach a correctness score of 61.7% (SD 14.2%), while TD-children at the same age are able to identify 90.3% (SD 8.0%) of the test items correctly (Hennies et 2012, 88). However, the children with HA still improve their ability to discriminate these

phonemes at this age (Hennies et al. 2012, 89). Thus, based on this pilot study alone, it is impossible to predict if they will catch up with hearing peers.
Since German speech audiometric tests do not test the ability to differentiate between phonemes in word- and syllable-final positions, the FinKon-test has been adapted for clinical audiometric setting (Stropahl & Hennies 2011): As a first step, the intelligibility of each test item has been measured and the level has been adjusted to the 50% speech recognition threshold (SRT) of the whole test list. As a second step, the test has been calibrated for further use in sound booths of clinics and early intervention centers. This paper presents the preliminary results of the collection of a norming sample as third step in the test development process. Three groups of children that are relevant for clinical work have been included: TD-children, children with HA und children with CI. In order to document the phonological development from the early intervention until the end of primary school, i.e. in a time that is crucial for the language acquisition and academic outcome of children with HA and CI, the norming sample covers an age range from 3;0 to 10;11.

METHOD
The test is designed as a picture-selection task based on a minimal-pair-method. The items are presented by the loudspeakers in the sound booth. There are two test blocks. The first test block consists of 13 items incorporated into picture triplets (e.g. fig. 1). One of the three pictures depicts the test item (e.g. *Huh**n*** 'hen') and the second picture shows the other part of the minimal pair, that only differs in the word- or syllable-final position (e.g. *Hu**t*** 'hat'). This word serves as a phonological distractor in order to test if children are able to hear this difference and thereby to discriminate between coronal consonants in offset positions. The third picture shows a word that begins with the same onset as the target word, but has a different nucleus and offset (e.g. *Haus* 'house'). This item is the (phonologically) unrelated distractor that enables the investigator to see, if the child is able to perform this task at all. All these words are part of the children's lexicon and consist of mono- and disyllabic nouns that can easily be depicted (for a detailed description of the test list see Hennies et al. 2012; in the norming sample two additional item pairs were included).
In the second test block these 13 minimal pairs and unrelated distractors are repeated with slightly different colors and different positions on the picture triplets. Now, the counterpart of the minimal pair is presented as test item (e.g. *Hu**t*** 'hat', with *Huh**n*** 'hen' as phonological distractor and with *Haus* 'house' as the (phonologically) unrelated distractor). Results are based on the pointing of the children alone and all reactions are recorded by paper and pen.

Fig. 1: example of a picture triplet (first test block)

RESULTS
As of February 2015 a sample of 63 TD-children, 72 children with HA, and 32 children with CI at the age of 3 to 10 has been collected. These children have been tested in several early intervention centers and clinics all over Germany during regular speech audiometry sessions. Most of these children were tested by project staff, in single cases the members of the early intervention centers were trained in the test procedure and tested the children on their own.

Beside the results of the FinKon-test additional data were collected, such as the pure tone audiogram of the children and the results of one of the most common speech audiometric tests for children, i.e. the *Mainzer Kindersprachtest* (Biesalski et al. 1974) or the *Göttinger Kindersprachverständnistest* (Chilla et al. 1976). All tested children grow up in a monolingual German home and none has additional handicaps, based on the information given by the cooperating institutions.
The children with HA have an unaided hearing threshold of 50 dB (HL) on average. These children received their first hearing aid at the age of 3;2 (SD: 2;0) and only 17 children were diagnosed and received hearing aids below the age of 1;6.
For children with CI the unaided hearing threshold is very often not reported, but based on the official recommendation in the German health system (Schattke 2012) it is safe to assume that these children have a hearing loss of more than 90 dB(HL). In this group there are seven children with only one CI whereas 25 have bilateral implants. These children received their first CI on average with 1;10 (SD: 1;1). 21 of these children have received their first CI within the first two years of their life and only three after the third birthday.
A lot of these children were born before the advent of universal newborn hearing screening (UNHS) in Germany in 2009, so especially the children with HA received their hearing device much later than comparable children in the UNHS, who received their first hearing aids at the median age of 4 months (Rohlfs et al. 2010, 1359). However, the children with CI in our study received their first CI even earlier compared to median age of implantation in an UNHS region (Rohlfs et al. 2010, 1359). Therefore specifically the children with HA in this study might not be fully representative for children with HA born after 2009, but in general they are already earlier diagnosed than has been reported for Germany before the UNHS (Finckh-Krämer et al. 2000).

In table 1 the age distribution of the TD-children, children with HA and children with CI in our study is presented. Because the data collection is still ongoing, there is a sufficient number of children in some age groups, but there still is a need for more children with CI in our study: Especially in the age range of 4;0-4;11 with only one child so far and in the age range of 7;0-7;11 with three children, the respective “groups” are too small to allow any conclusions for children with CI of this age. Therefore in the representation of the preliminary results in fig. 2, every group with less than six children is represented by a transparent bar in order to indicate that these data do not indicate any reliable tendency so far.

age	TD	HA	CI
3;0 -3;11	11	6	6
4;0 – 4;11	11	10	1
5;0 - 5;11	8	11	10
6;0 – 6;11	13	12	6
7;0 – 7;11	10	12	3
8;0 – 10;11	10	21	6
N=	**63**	**72**	**32**

Table 1: Age distribution of TD-children, children with HA and children with CI

The preliminary results in fig. 2 illustrate the development in the three groups: TD-children reach a correctness score of 75.6% (SD: 9.2%) in their choice of the target item with three years and 89.9% (SD: 8.1%) with four years. This improvement between the age of three and four is consistent with the results of the pilot study (Hennies et al. 2012), indicating that TD-children are still developing their phonological system at this age. The TD-children in our study also show a slow improvement afterwards up to 100%. All ten TD-children above 8;0 manage to achieve the perfect score. It is likely that this slight increase in the performance after the age of four rather results from a better test performance and concentration in the older TD-children than from a more fine grained phonological system. Within the TD-group

there is a high and significant correlation between age and test scores (Spearman‘s ρ(46)= 0.83, p=.000).
Children with HA are also showing a slow, but steady improvement between the age of four and seven, when they reach a correctness score of 85.3% (SD:13,9%), that is still slightly below the 90%-mark. In contrast to the results of the pilot study there is no significant gain between the age of three and four in this study (Hennies et al. 2012), which might, however, be explained by the small sample size of the group of three-year-old children with HA (n=6). In the whole group of children with HA there is a high and significant correlation between age and test scores (Spearman‘s ρ(63)=0.56, p=.000). Although there is significant progress, children with HA do not catch up with their hearing peers. However, they reach an almost comparable level as TD-children with four years, when they are already attending school, i.e. at the age of seven and above.
The children with CI show a more heterogeneous picture: Their performance is below the results of the hearing TD-children and below those of the children with HA as well. However, one has to keep in mind that the latter have much better residual hearing. The nine children with CI that are seven years and older in this study only reach a correctness score of 76.0% (SD: 20.2%) on average. Although there is a significant correlation between age and test score in this group (Spearman‘s ρ(22)=0.44, p=.012), the development over time appears slower in children with CI than in two the other subject groups in this study.
Based on the chronological age there is a high group effect in this study, proving that TD-children have better results than children with HA and that these children outperform children with CI (Kruskal-Wallis, p=.000). This effect can also be found, if children with CI and HA are compared to TD-children based on their ‘hearing age’, i.e. when the length of exposure to spoken language with a hearing aid or CI is compared to the chronological age of the TD-children (Kruskal-Wallis, p=.001).
Summarizing the results of the norming data of the FinKon-test so far, there is a need for a speech audiometric test investigating the ability to discriminate the coronal consonants that are important for the acquisition of German subject-verb-agreement-morphology. Children with HA and CI show a reduced ability to discriminate these phonemes in the syllabic offset a long time after they have entered school. The mild to severe hearing impaired children of the HA-group perform significantly better than the children with CI and improve their competences steadily over the years. For the children with CI the results are still preliminary because of the uneven distribution of children over the age groups. If these data prove to be representative for this clinical population, they will also show a significant gain, but it is on a lower level and with less velocity compared to the HA-group. A group comparison based on chronological age and ‘hearing age’ supports this interpretation.

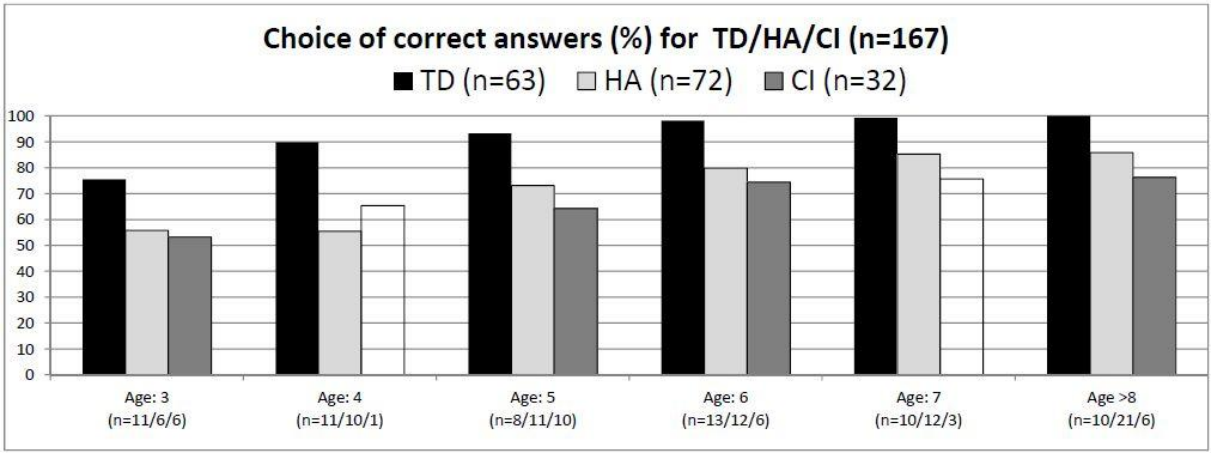

Fig. 2: Choice of correct answers in TD- children, children with HA and children with CI

CONCLUSIONS
Based on the preliminary results it seems important for the clinical diagnosis and for hearing aid- and CI-fitting to test the ability to discriminate coronal consonants in word- and syllable final positions. The data from the Finkon norming sample indicate that children with HA and

children with CI do not necessarily undergo a comparable development and might need different intervention strategies. While there is a fair chance that a lot of children with HA will reach sufficient competences in their ability to discriminate coronal consonants in word- and syllable-final positions, for the CI children this cannot be concluded so far. When the norming sample is completed, a more detailed analysis will be necessary in order to identify variables that influence the results of children with HA and children with CI as well as deeper within- and between-groups-analysis. The results so far indicate that the Finkon-Test is a valuable diagnostic tool and makes a significant contribution to the speech audiometric diagnosis of children with HA and children with CI.

ACKNOWLEDGMENTS

The research reported in this paper was supported by a German research foundation (DFG) grant to Markus Hess, Martina Penke, and Monika Rothweiler (project number: HE 2869/6-2, PE 682/2-2, RO923/1-2). We are grateful to parents and children, clinics, schools and intervention centers in Berlin, Bremen, Hamburg, North Rhine-Westphalia, Rhineland-Palatinate, Schleswig-Holstein and Thuringia. We would like to thank Maren Stropahl for her participation in the technical adaption and data collection and Lena Michalik for the illustrations of the test material.

REFERENCES

Biesalski, P., Leitner, H., Leitner, E., and Gangel, D. (1974). Der Mainzer Kindersprachtest. *HNO 22*, 160-161.

Chilla, R., Gabriel, P., Kozielski, P., Bänsch, D., and Kabas, M. (1976). Der Göttinger Kindersprachverständnistest I: Sprachaudiometrie des «Kindergarten-» und retardierten Kindes mit einem Einsilber-Bildertest. *HNO 24*, 342-346.

Finckh-Krämer, U., Spormann-Lagodzinski, M., and Gross, M. (2000). German registry for hearing loss in children: results after 4 years. *International Journal of Pediatric Otorhinolaryngol 56(2)*, 113-127.

Grijzenhout, J. (2001). Representing nasality in consonants. In Hall, T. A. (Ed.), Studies on Distinctive Feature Theory (pp. 177-210). Berlin: Mouton de Gruyter.

Hennies, J., Penke, M., Rothweiler, R., Wimmer, E., and Hess, M. (2012). Testing the Phonemes relevant for German Verb Morphology in Hard-of-Hearing Children: The FinKon-Test. *Logopedics Phoniatrics Vocology, 37:2,* 83-93.

Penke, M., Wimmer, E., Hennies, J., Rothweiler, M., and Hess, M. (2014). Inflectional morphology in German hearing-impaired children. *Logopedics Phoniatrics Vocology*, 1-18. Posted online September 1, 2014 doi:10.3109/14015439.2014.940382.

Pittman, A.L., and Stelmachowicz, P.G. (2003): Hearing loss in children and adults: audiometric configuration, asymmetry, and progression. *Ear and Hearing 24,* 198–205.

Rohlfs, A.-K., Wiesner, T., Drews, H., Müller, F., Breitfuß, A., Schiller, R., and Hess, M. (2010). Interdisziplinary approach to design, performance and quality management in a multicentre newborn hearing screening project. Introduction, methods and results of the newborn hearing screening in Hamburg (Part I). *European Journal of Pediatrics 169*, 1353-1360.

Schattke, R. (2012). Frühe Hörgeräte- und CI-Versorgung aus Sicht der Krankenkassen und des Medizinischen Dienstes. In A. Leonhardt (Eds.), Frühes Hören: Hörschädigungen ab dem ersten Lebenstag erkennen und therapieren (pp. 147–162). München: Reinhardt.

Stropahl, M., and Hennies, J. (2011). Optimierung von Tonmaterial für die Entwicklung eines sprachaudiometrischen Kindertests. *Zeitschrift für Audiologie 50 (4),* 138–146.

Vennemann, T. (1988). *Preference laws for syllable structure and the explanation of sound change: with special reference to German, Germanic, Italian, and Latin.* Berlin: Mouton de Gruyter.