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Assessment of auditory processing in children demonstrating symptoms of (Central) Auditory processing disorder (C)APD

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(Central) auditory processing describes functions such as sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition (e.g., temporal gap detection), temporal ordering, and temporal masking; auditory performance in competing acoustic signals (including dichotic listening); and auditory performance with degraded acoustic signals. Poor performance in one or more of these abilities without signs of degraded abilities of higher order cognitive/communicative and/or language-related functions might be a symptom for (Central) Auditory processing disorder, (C)APD. For school-aged children, (C)APD can manifest itself in difficulties in learning, speech, language, social, and related functions. However, depending on individual combinations of "bottom-up" and "top-down" abilities, the same aspect of auditory processing deficit may influence different children in different ways, which makes standardised ways of a diagnostic approach difficult to establish. During the last two years, a multidisciplinary team at Uppsala University Hospital has worked on diagnosis and management of children demonstrating symptoms of (C)APD. Results of measurements of auditory processing of 50 children as well as approaches to manage their problems are presented and discussed.

INTRODUCTION

Auditory Processing Disorder (APD) is a diagnose to be considered on the basis of difficulty in identifying or discriminating sounds despite normal hearing thresholds. Difficulty in understanding speech in noise is the most common manifestation, but other symptoms such as problems remembering orally given instructions, localising sounds or abnormal sensitivity for loud sounds may also occur (ASHA, 2005). Research on diagnosing APD has been done in several years, but there are still discussions of the feasibility of some test procedures, and of associations of APD with learning and language problems (Moore, 2006). Even though there have been several suggestions on how to develop relevant, multiprofessional diagnostic approaches (Witton, 2010), such diagnostic approaches have been hampered by considerations on co-morbidity of APD with other problems such as language and/or

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reading disorders (Sharma *et al.*, 2009), approaches on training programs and technical rehabilitative solutions for children with APD (Putter-Katz *et al.*, 2008, Johnston *et al.*, 2009), and new considerations about the underlying mechanisms of auditory processing deficits (Moore *et al*., 2010). Therefore, for many professionals working with children's communication, APD is not a very well known condition and more information on both background and management is necessary (Logue-Kennedy *et al*., 2011).

During the past years, many children with hearing problems despite normal hearing thresholds were referred to the Hearing- and balance section at Uppsala University Hospital. With the fact of an increasing waiting list for diagnosis and treatment of these children, we established a multidisciplinary group in order to work on this issue.

SUBJECTS

Fifty children and young adults who were consecutively referred to our clinic with hearing difficulties despite normal or almost normal hearing thresholds were included in this analysis. The study group consisted of 44% girls and 56% boys with a median age of 11 years (range: 6.5 – 18.6 years). At this stage no control group is established yet.

METHODS

During an initial visit with a physician specialized in audiology, the case history was taken and assessments of speech-language therapists and/or school psychologists were monitored. A two-step diagnostic approach was then applied. The first session with an audiologist (about 2 hours) consisted of measurement of hearing thresholds, measurement of acoustic reflexes during ipsi- and contralateral stimulation, speech audiometry with and/or without background noise, Transiently evoked Otoacoustic Emissions (TEOAE) and automated Auditory Brainstem responses, aABR. In the case of an unsecure aABR, also a clinical ABR was performed. This session was mainly a tool to rule out the possibility that the symptoms were related to an Auditory Neuropathy. The second session (about 3 hours) contained Gaps in Noise (GiN) (Shinn *et al*., 2009), identification of duration- and frequency-patterns (Musiek, 1994) as well as dichotic listening tests in both free and directed report modes with numbers and syllables (consonant-vowel combinations, CV) as stimuli (Hällgren *et al*., 1998).

Normal values for the measurements in step two were taken from the literature with Musiek (2005) and Shinn *et al*. (2009) for GiN, Bellis (2003) for duration- and frequency patterns as well as Köbler *et al*. (2010) and Hällgren *et al*. (1998) for the dichotic tests. For the dichotic tests, results within 10% lower than the reported values were accepted as normal. If three or more of the measurements showed deviant results, the child most often received the diagnosis "APD" and were referred to the Uppsala Hearing Clinic, where practical advice on how to generally deal with

hearing problems was provided and in several cases even a personal FM system. Also counselling for school personnel was offered.

RESULTS

Most of the children completed all tests and a considerable amount showed deviant results in pattern recognition and the dichotic CV-test, see table 1.

	Number of subjects measured	Number of deviant results
GiN	45	19
Duration pattern	48	43
Frequency pattern	47	39
Dichotic numbers	49	17
Dichotic CV	48	44

Table 1: Number of subjects measured in the different central processing tests and number of subjects with deviant results in at least one ear.

For the pattern recognition tests and in some extent for the GiN, children showed generally more bilateral deviations than occurred for the different dichotic tests, where unilateral deviant results were more common, see figure 1.

For those children showing deviant results, a multivariate analysis of variances with a general linear model for repeated measurements for all tests with "ear" as within factor and "gender" as categorical factor was performed.

For the GiN, no statistical significant differences between ears or gender could be observed. Even though right ear deviations were more common for the duration pattern recognition, right ear results were statistically significant better than left ear results ($p<0.05$). Post-hoc tests (Least square differences) for "ear" and "gender" showed that this difference was persistent for the girls, but not for the boys.

For the frequency pattern recognition no statistical significant differences between ears or gender could be observed. For the dichotic tests, no significant different results for right and left ear or boys and girls were obtained for the test with numbers. For the CV-test, however, statistically different results due to the right ear advantage (Hällgren *et al*., 1998; Köbler *et al*., 2010) were expected and obtained. We observed a statistical significant better performance for the free recall situation than the directed recall situation for the test with numbers for both ears ($p<0.05$ for the right and $p<0.001$ for the left ear). For the CV-test however, better results for the directed report was observed, but only for the right ear ($p<0.05$). No gender effects were observed for these tests.

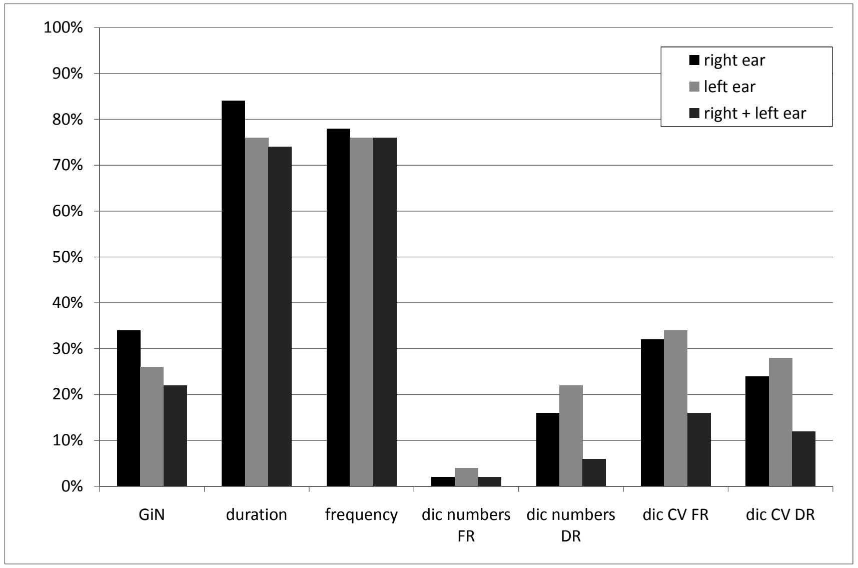

Fig. 1: Number of unilateral and bilateral deviant results for GiN, duration pattern recognition, frequency pattern recognition, dichotic test for numbers and CVs, free and directed report. Black columns indicate right ear, light grey left ear and dark grey deviations in both ears.

DISCUSSION

In this study, we investigated the central auditory signal processing in children who were identified to have hearing problems despite of normal hearing thresholds in such an extent that the problems led to difficulties e.g. in school. Measures used were temporal resolution in terms of the Gaps-in-Noise test, GiN, duration pattern recognition, and frequency pattern recognition as well as dichotic testing.

In previous studies, lesions in the central nervous system (CNS) led to increased thresholds in gap-detection tasks (Efron *et al*.,1985; Syka *et al*., 2002). As the GiN-test has shown to be sensitive for CNS lesions in humans (Musiek *et al*. 2005; Bamiou *et al*., 2006), we assume that those children demonstrating poor performance in this test can probably be considered to have degraded temporal processing caused by CNS involvement. We cannot determine if this degraded temporal processing is linked more to the auditory pathways or if there is a dysfunction on the cortical level.

A huge part of the referred children showed deviations for both the duration- and frequency pattern recognition tasks. Even though these tests are sensitive for brain lesions (Bamiou *et al*., 2006), a certain amount of working memory capacity is needed to perform this task. Recent research has stated that APD might not be

caused by deficits in signal processing, a “bottom-up” process, but rather by problems with attention and concentration, “top-down” processes (Moore, 2010). Of those children with deviating results in either duration- or frequency pattern recognition, five had a Attention-Deficit/Hyperactivity Disorder (ADHD) diagnosis, one had diagnosed Aspergers syndrome, one had confirmed concentration problems and one problems with working memory. Those children’s results in the pattern recognition were definitively influenced by attention issues, but the results of the remaining children might nevertheless reflect a degraded auditory processing regarding temporal resolution.

The purpose with the dichotic tests in this stage of our investigation was to have a possibility to differentiate between auditive and cognitive aspects of the children’s hearing problems. During a dichotic listening task, the subject is instructed to either report both signals in optional order (free recall, FR) or to disregard one of the signals and only report the signals reaching one predefined side (directed recall, DR). During FR conditions, both ears have to be monitored simultaneously and the subject has to remember one of the signals while reporting the other. Therefore, cognitive factors influence FR more than DR conditions, where the cognitive demands are reduced. Substantial better performance during the DR condition compared with the FR condition can therefore indicate cognitive dysfunction (Carter *et al*, 2001). Also here, the observed better performance in the free recall situation for the number test, as reported in the “Results”-section, might indicate, that the children rather had problems with attention. The directed report is demanding in the respect, that the subject has to be able to remember the reporting side simultaneously with reporting the signal. This task might be demanding for children with poor attention performance. The auditory more demanding task of dichotic CVs did nevertheless not show the same pattern as the test with numbers. There we observed a significantly better performance in the directed situation, but only in the right ear. Cognitive issues instead of auditory processing problems can therefore not be totally disregarded in our material.

CONCLUSIONS

Measurement with common tests for central auditory processing on 50 children with hearing problems despite normal hearing thresholds showed that almost all children had some kind of deviation from normal values for at least one of the tests. We could not clearly determine if the underlying reason for the problems were mainly auditory or connected to attention deficits for most cases. Tests for auditory attention or/and working memory should possibly be included in the test-battery in order to obtain more reliable results.

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