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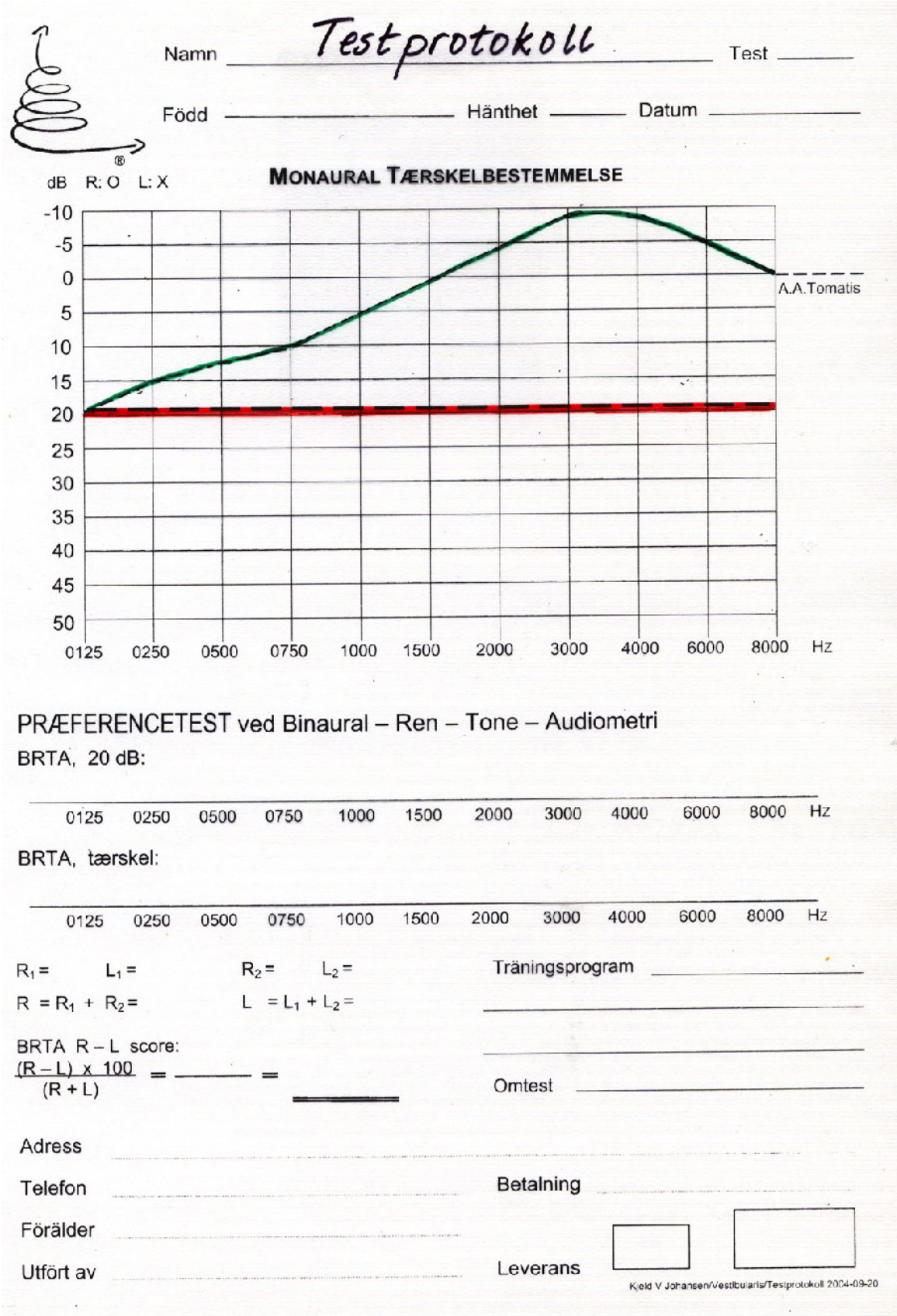
Auditory perception is of importance for learning and for sustainable health

Introduction

Why, usually, does just one child or a few children fare badly from sound, for instance in a noisy classroom. Why not all of them?
Why is it just one or a few children who can't stand the noise and might rush out of the class room. Why not all of them?
Why is just one person struck by tinnitus after for example a concert when so many are exposed to the same sound?
One explanation might be that people have different Auditory Perceptual Profiles (APP).
When a person has a well balanced APP (curve) he or she also has increased possibilities to handle different impressions of sounds which make it easier to handle noisy environments.

The APP or curve referred to is 'Tomatis optimal hearing curve' which was empirically developed (1) by A.A Tomatis. Over the years the curve has been criticized both because of the lack of statistical information of how conclusions were reached and because of the lack of validation. In his autobiography (2) Tomatis states that validation of his method on the effects on children's learning processes was carried out in cooperation with three North American Universities but he does not mention how and where the results were published.
Despite the lack of scientific proof and validity the empirical knowledge gained from auditory perceptual assessments and training ought to be of importance in different areas. Tomatis writes (2) that his method is not only a medical issue but also a psychological issue as well.



Picture 1. The Audiogram, Assessment sheet used during testing.

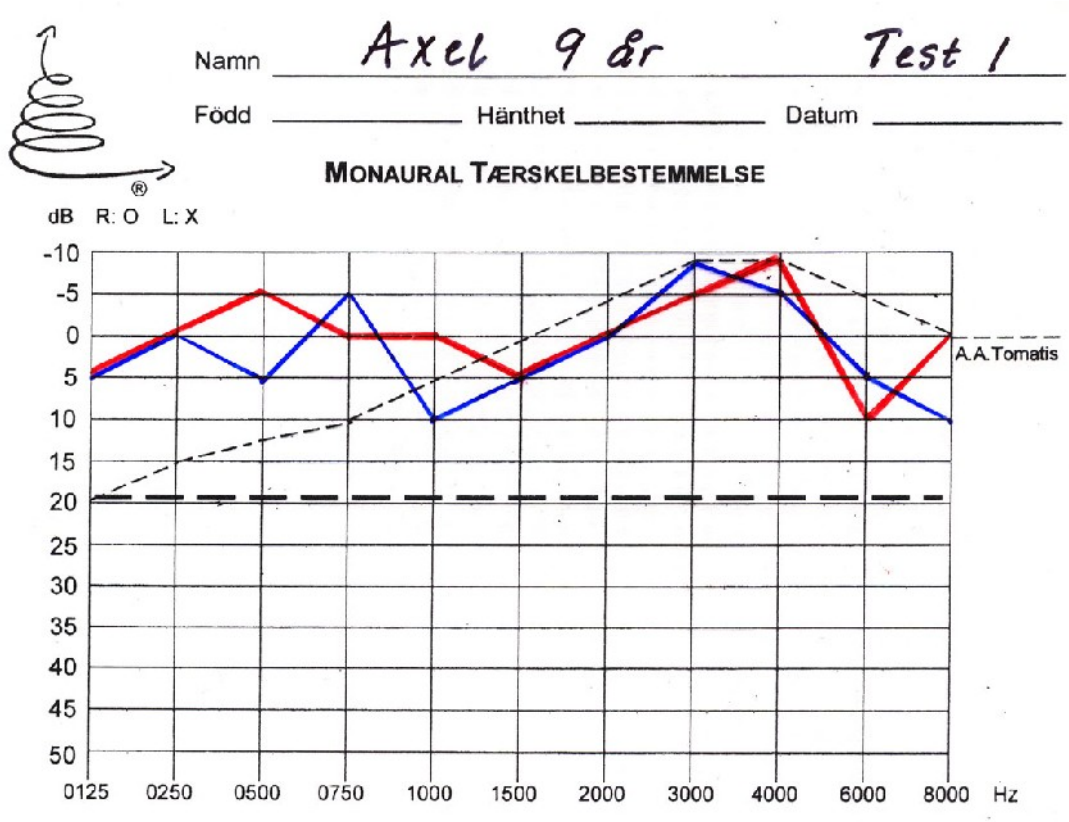
The audiogram

The audiogram is a graph on which the results are to be plotted. The frequencies, measured in Hertz, are shown on the horizontal axis and the intensity, measured in decibel, is shown on the vertical axis, reading downwards from the lowest decibel level at the top.
The intensity of 20 decibel, the red line, equals a whisper. This is the level measured by the health care with-in the Swedish school system. According to praxis, hearing at the 20 dB level within the frequency range of 125 Hz – 8.000 Hz equals good enough hearing.
However, despite such a result a person might have severe auditory perceptual problems.
Shown along the horizontal axis is the frequency range. In General 125 Hz to 750 Hz is the base range while 3.000 Hz to 8.000 Hz is the treble range but the frequency range is continuous. Around 1.500 Hz 'the emotional range' can be identified.
The human ear can perceive sounds as high as 20.000 Hz and 'unfortunately' also sounds at a level as low as 15 Hz. 'Unfortunately', because quite often, both in offices and in schools, there are ventilation systems which operate on low frequencies. When such a system is turned off a relief can be felt in the whole body. Low frequency noise is in other words very tiring.

Auditory Perceptual Profile (APP)

Assessing a person testing 20 dB along the frequency line does not give enough information. Instead a search to identify the lowest tone for each successive frequency is necessary. The results which are plotted in the graph will form the clients personal **Auditory Perceptual Profile (APP)** or curve. The profile or curve is then to be compared to the green line which is the line of Tomatis'. Tomatis was a French medical doctor (MD) who already in the 50's, through his research, showed that the human ear is able to, or should be trained to, better perceive within the treble range compared to the perception within the base range (which shouldn't exceed the green line).
If the APP shows a distinct difference between the base range and the treble range the client is more prone to handle and to endure sound and noise better.

However, the profile must not exactly follow the green line but worth aiming is a harmonious curve which mirrors the green line.
Below is an example from an assessment of Axel nine yrs old.



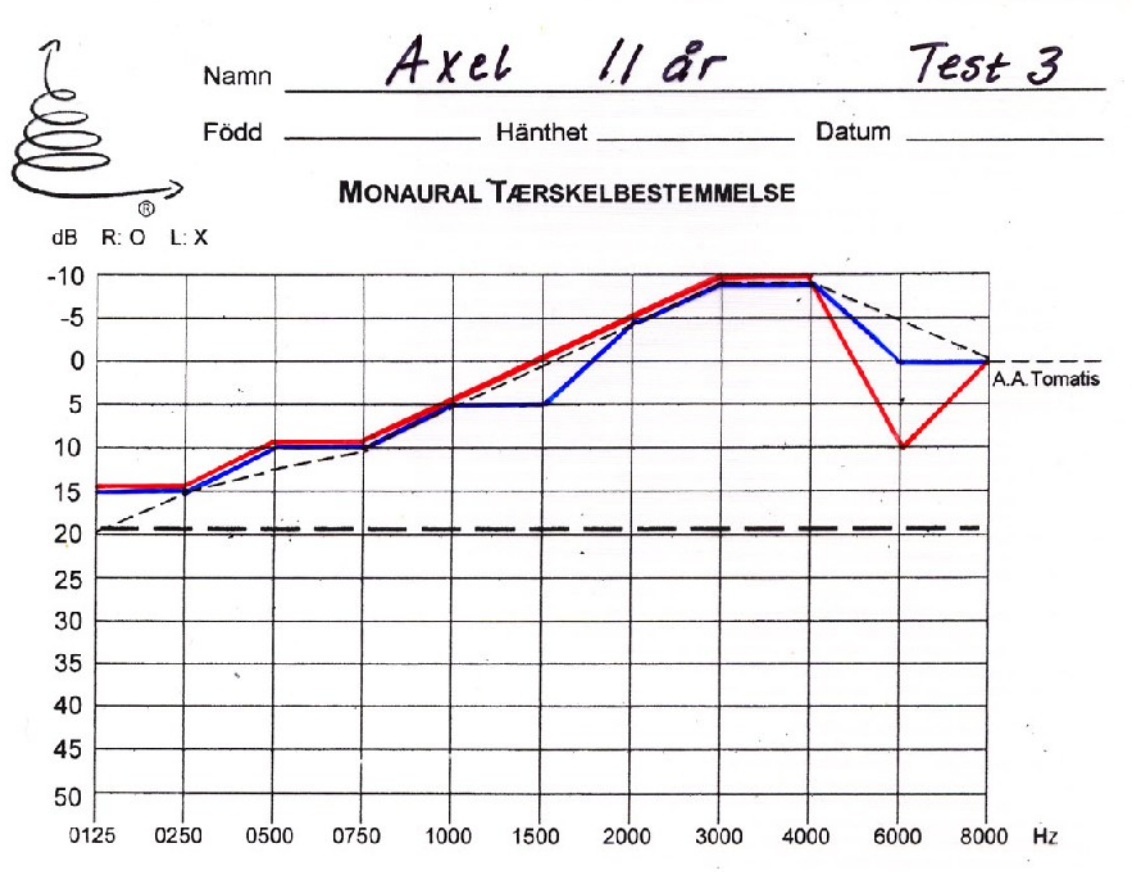
Picture 2. The blue line is the left ear and the red line is the right ear.

Axel's main problem is his perception within the base range. His auditory perception has exceeded the (green) line of Tomatis' which means that he is very sensitive to certain sounds and noises such as people when mingling, lorries, cars, fans, ventilation systems and Hoovers. Even the scraping from chairs in the class room will affect him.

Producing a CD

The method Johansen Individualised Auditory Stimulation (JIAS), developed by the Dane Kjeld V Johansen (3) is used to produce a custom made CD. The music which is especially composed by another Dane, Bent Peder Holbech (4) is stored in the computer and follows Tomatis' (green) line.

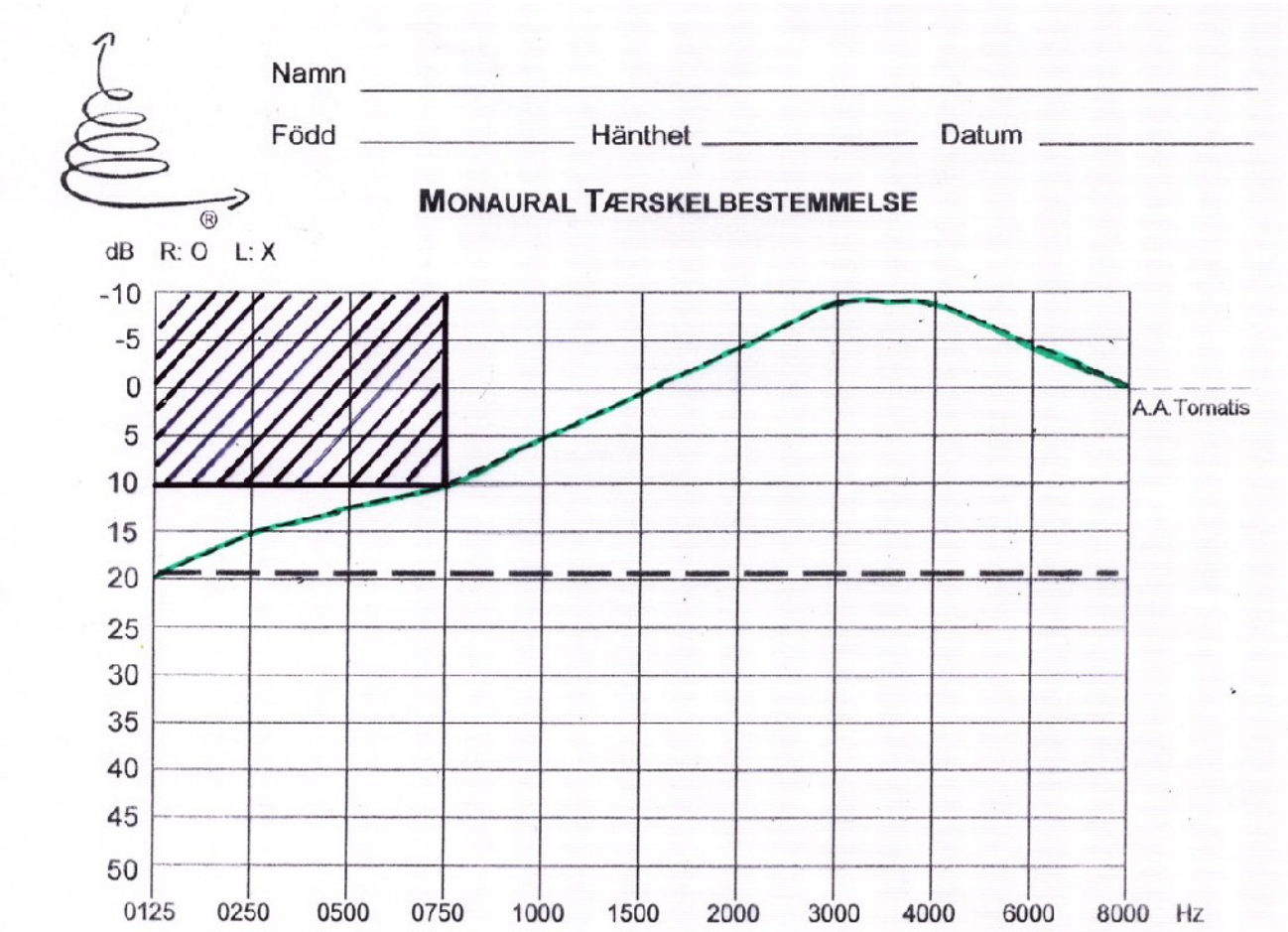
The music is manipulated through the use of the computers equalizer. According to the plots in the graph (the APP) the equalizer is used to manually increase or decrease the intensity within each frequency range.
The custom made CD which will be **listened** to in headphones 10 minutes daily through at least 12 weeks with the aim to shape the auditory perception and bring it as close as possible to Tomatis' (green) line.
Below is Axel's APP after training. Today he is doing well at school and the over-active and provocative behavior he used to show is gone.



Picture 3. Axel after training.

Auditory perceptual difficulties within the base range

A deviation within the area of the frequency range 125 Hz to 750 Hz and with the intensity range of 10 dB to -10dB (low levels) can be defined as a **sensitivity within the base range.** The health care system, though, usually refers to higher dB levels when defining deviations.



Picture 4.

One reason why Axel's problem wasn't identified at school is the medical praxis of measuring only 20dB. By continuing to do so, important information about probable reasons for children's behavior is missed out. It is important to measure whether or not a child hears but it is equally important to measure **how a child hears**.
Observations in connection to APPs produced since 1995 are that sensitivity within the base range had increased over the years and the results of this problem becomes more obvious. There are lots of evidence pointing toward a more hectic and stressful environment for children as well as for adults, today compared to the mid nineties. The problems we face today are in many ways more complex and more people are obviously feeling worse.

A naturalistic pilot study

The main purpose of a naturalistic pilot study, first presented at an international conference on the Azores in 2007 (5), was to examine if auditory perceptual problems within the base range had increased over time among clients at Vestibularis. Further questions to be answered were; If so, do we need to be more observant? If so, why?
Two hypothesis were stated

1. Sensitivity within the base range (125 Hz –750 Hz) is increasing.
2. Sensitivity at or around the frequency of 6.000 Hz is increasing.

Participants

1.477 first assessment audiograms accomplished between 1995 and 2007 were divided into two periods, 1995-2000 and 2001-2007.
Period 1, 1995-2000 is basically the period when the clients were one and the same as the ones who were trained at Vestibularis.
Period 2, 2001-2007 includes participants who were tested by people trained in the JIAS (ADT) method by the author.
Boys / males were separated from girls / females and their age was arranged according to Piaget's Cognitive – Developmental Theory (6) and adults added.

1. Up to (from about age five) seven years of age. (The Preoperational thought stage).
2. Seven to eleven. (The Concrete Operational stage).
3. Twelve to adulthood (here 18 yrs). (Formal Operations stage).
4. Adults

Participants

Period 1 1995 - 2000				Period 2 2001 - 2007			
Age	M+F	M	F	Age	M+F	M	F
→ 6	96	80	16	→ 6	81	57	24
7 - 11	342	279	63	7 - 11	336	239	97
12 - 18	115	85	30	12 - 18	148	92	56
19 →	72	21	51	19 →	287	79	208
Total:	**625**	**465**	**160**	**Total:**	**852**	**467**	**385**

Period 1 and 2 in all:	Participants	1.477
	Male	932
	Female	545

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Picture 5. Participants.

Scoring

The area of scoring is shown below.

Scoring

Age	125 Hz - 750 Hz	1500 Hz	3000 Hz - 4000 Hz	6000 Hz / 6000 Hz below 20 dB
→ 6				
7 - 11				
12 - 18				
19 →				

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Picture 6. Scoring.

Area 1. 125-750 Hz, a mark for each score *above* Tomati's curve was made.
Area 2. Around 1.500 Hz, the 'emotional range', an area which most probably can be connected to the emotional- and inner life.
Area 3. 3.000 – 4.000 Hz, a part of the treble range.
Area 4. 6.000 Hz, where signs of a low stress threshold can be found.

Each obvious divergence from Tomati's optimal curve within each range was scored blue for males and red for females. Each participant could be given a score in one, two, three or all four areas.

Age span 1 and 3 were excluded in order to focus on the ages seven to eleven (age span 2) and adults (age span 4).

This priority was done because an appropriate time for learning to read is around age seven and eight as stated by Bakker (7) and because adults with fatigue problems are an increasing group among clients.

Results

Distribution

Time, Age and Frequency Range in per cent (%)

	125 Hz - 750 Hz	1500 Hz	3000 Hz - 4000 Hz	6000 Hz / 6000 Hz below 20 dB	M F
age 7 - 11 1995 - 2000	39	32	85	85 / 26	342
age 7 - 11 2001 - 2007	53	29	85	83 / 29	336
age 19 → 1995 - 2000	50	43	83	88 / 41	72
age 19 → 2001 - 2007	61	39	84	85 / 52	287

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Picture 7. Distribution in %. See also Appendix, Pictures 16 and 17.

1. Difficulties within the base range have increased in both age groups.
In group one from 39 % to 53 %. Total increase 14 %.
In group two from 50 % to 61 %. Total increase 11 %.

2. Difficulties within the treble range are equally distinctly high in both age groups during both periods.

3. When it comes to 6.000 Hz the same pattern was found in both age groups.
4. Going one step further, looking at the dip below the level of 20 dB, an increase of 3 % in the younger group and an increase of 11 % in the adult group was found.

Hypothesis one, sensitivity within the base range (125 Hz –750 Hz) is increasing was confirmed. In age group 7 – 11 the increase is 14 % and in the adult group there is an increase of 11 %.
However, a further inquiry focusing only on 2005-2007 and presented at a national school conference in Stockholm, Skolforum 2007(8) gave results as showed below.

Clients with deviations, defined as sensitivity, within the base range, 125 Hz-750 Hz

A Clients at Vestibularis 2005 - 2007
B Clients at Providers 2005 - 2007

A			B		
Age	M + F	Deviations M + F	Age	M + F	Deviations M + F
→ 6	17	10 59%	→ 6	12	8 67%
7 - 11	38	30 79%	7 - 11	91	53 58%
12 - 18	13	10 77%	12 - 18	41	18 44%
19 →	69	53 77%	19 →	71	47 66%
	137	103 75%		215	126 59%

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Picture 8. See also Appendix, Picture 18.
Group A: Clients tested by the author.
Group B: Clients tested by persons trained by the author.
The author made the CD's for all clients in both groups.

Looking at group A and the ages 7-11 a doubling from the mid 90's was found, 39 % to 79%. Once again the hypothesis was confirmed. High scores in the other age groups are also shown in the chart.

Looking at group B and the ages 7-11 the percentage is lower than in group A (58%).

In preparation for this current presentation an even further inquiry was done which included the time span up until now (2009). A continuing negative trend in group A, age span 7-11, 85% was found.
In group B the percentage is still lower, 49%, in age span 7-11 but amongst the adults the percentage has increased.

Clients with deviations, defined as sensitivity, within the base range, 125 Hz-750 Hz

A Clients at Vestibularis 2007 - 2009
B Clients at Providers 2007 - 2009

A

Age	M + F	Deviations M + F
→ 6		
7 - 11	26	22 85%
12 - 18		
19 →	39	30 77%
	65	52 80%

B

Age	M + F	Deviations M + F
→ 6		
7 - 11	35	17 49%
12 - 18		
19 →	10	8 80%
	45	25 56%

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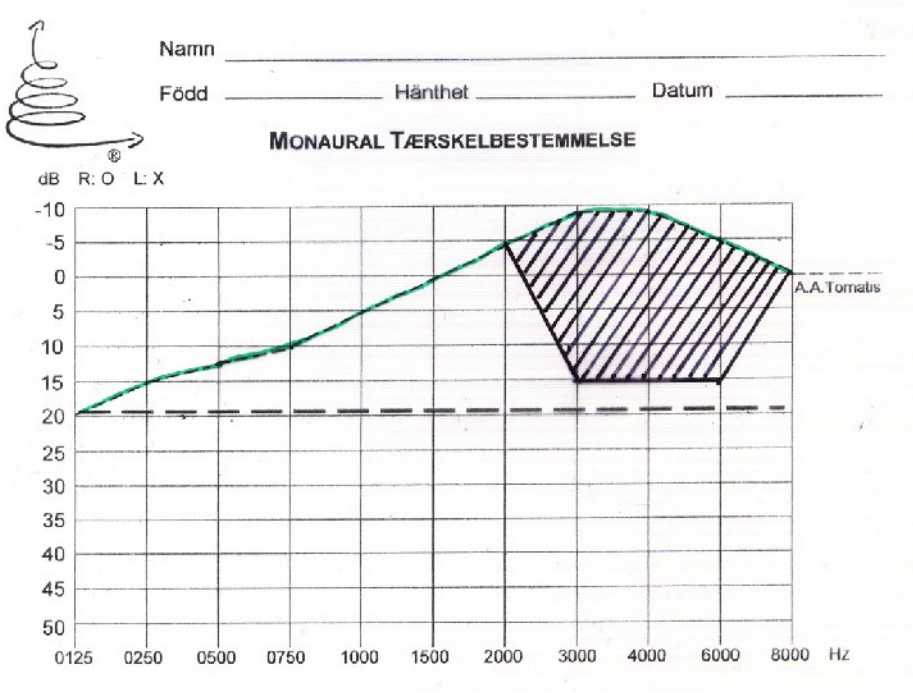
Picture 9.

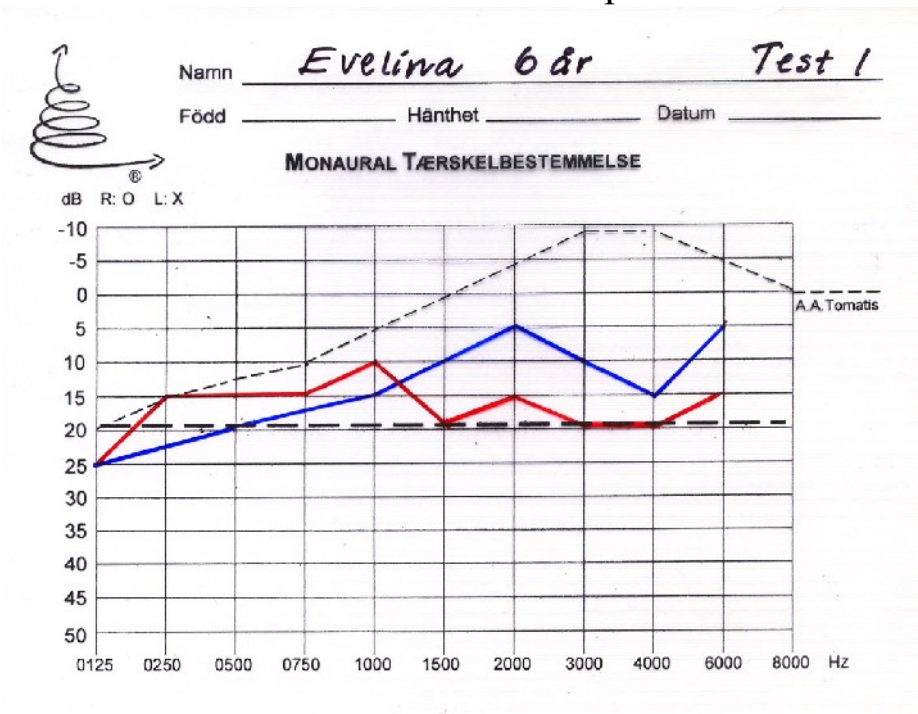
A possible explanation for the difference between the two groups might be that group A is assessed and trained within the setting of Vestibularis (9,10), a movement school, to which parents bring children showing problems mainly within the field of Developmental Coordination Disorder (11). DCD is defined as sensorimotor problems without obvious medical reasons. Associated to DCD are reading and writing difficulties as well as concentration problems.
On the other hand, group B is assessed and do their training within the setting of the traditional school system. Within the traditional school system it might be more natural to connect ’silent children’ and children with mainly reading and writing difficulties only to auditory perceptual problems not to DCD.
In connection to hypothesis one the question, ‘If so, do we need to be more observant?’ was asked and the answer is Yes!
Some of the problems identified in connection to auditory perceptual sensitivity within the base range are;
Increased fatigue, which means increased tiredness or weariness and concentration problems. **Learning disabilities,** sometimes because the child is more easily distracted. **Behavior problems** which might show as daydreaming and/or temper outbursts. Among older clients there is a tendency of them **getting more easily frustrated** in efforts with the result of them walking away. There is also a tendency of **increased stress** and **communication problems** because they can’t hear what is said.
There are also reasons to suspect that exposure over a longer time to low intensity sounds within the base range, such as computer games and ventilation systems, might harm the auditory perception.

The treble range



Picture 10. An area of the treble range which requires a more subtle perception.

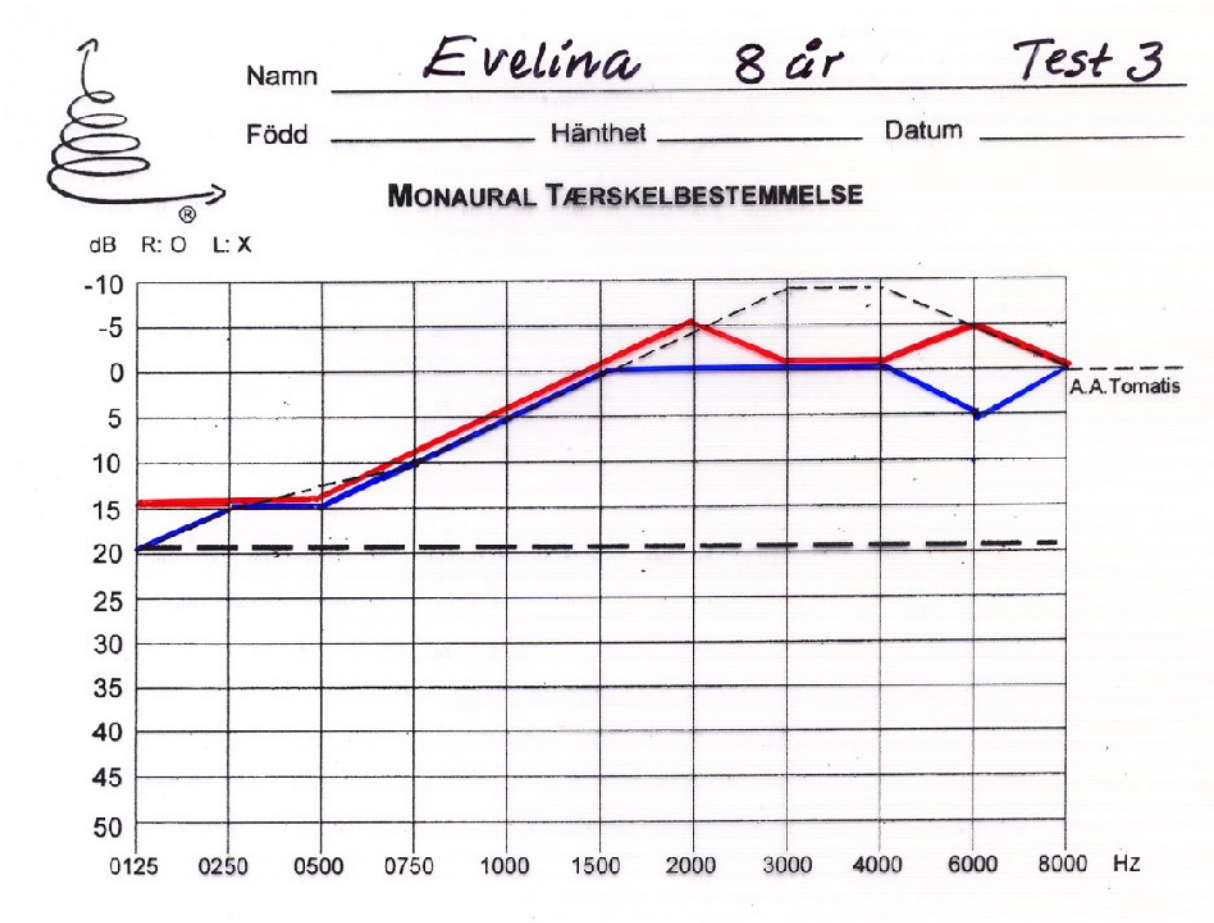
Below is Evelina's APP shown as an example.



Picture 11. Evelina 6 years old, before training.

Evelina's APP shows her initial optimal capacity and another type of sensitivity. She was not able to perceive properly at 3000 Hz – 4000 Hz. In connection to such sensitivity the following problems have been identified;
Higher frequency sound might be perceived as **painful**, **holding** one's hands to one's ears, **learning** difficulties, **speech** problems, difficulties in **pronouncing**, difficulties in handling **noisy environments**, difficulties in **nuance one's own voice**,
talks in a **loud voice** and **misunderstands** and asks again.

Below is Evelina's APP after training. After last assessment she was doing well at school.

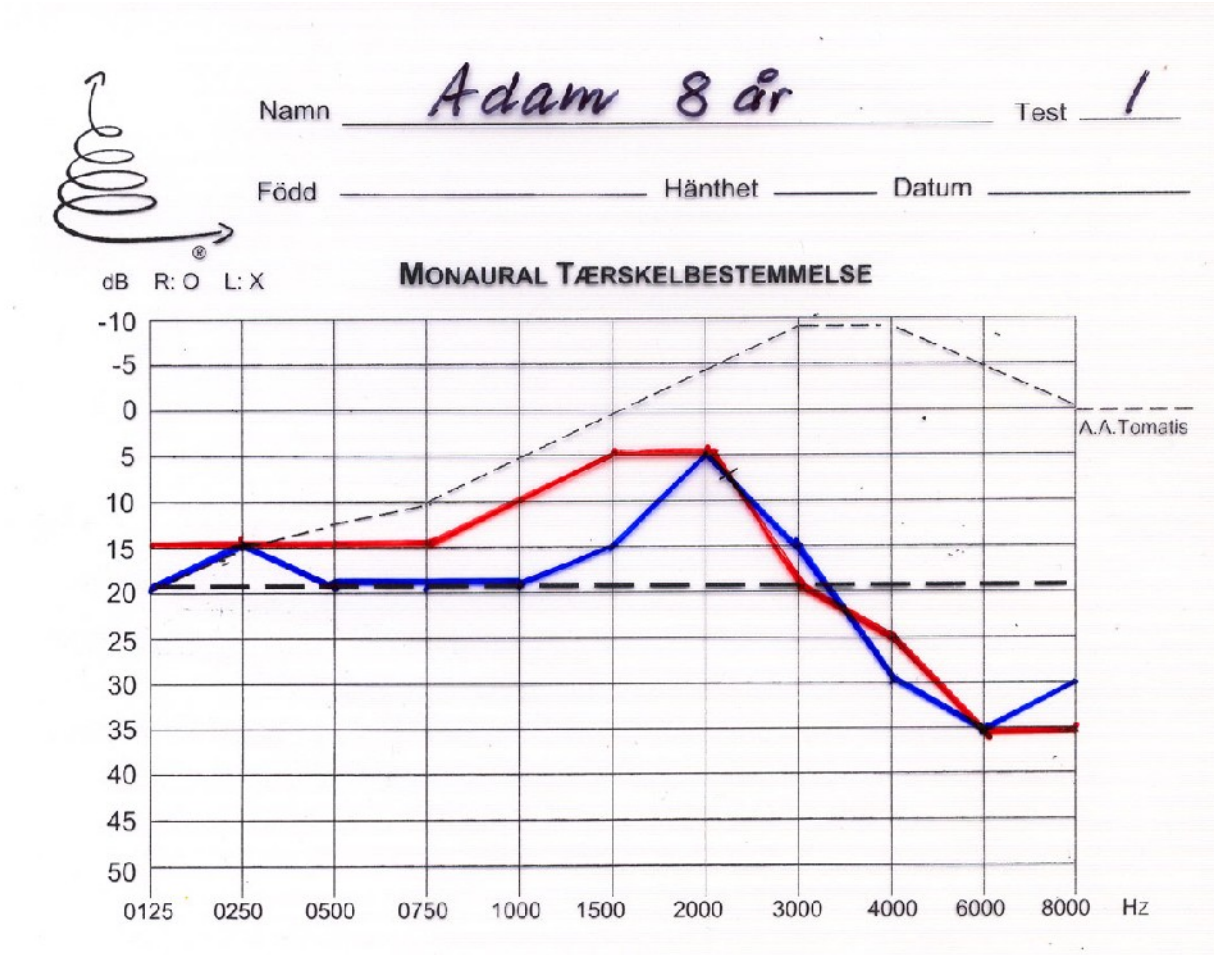


Picture 12. Evelina 8 years old, after training.

The area around 6.000 Hz

The concept of 6.000 Hz is of importance because its close relation to '**stress-sensitivity**'.

Below is Adam's APP shown as an example.

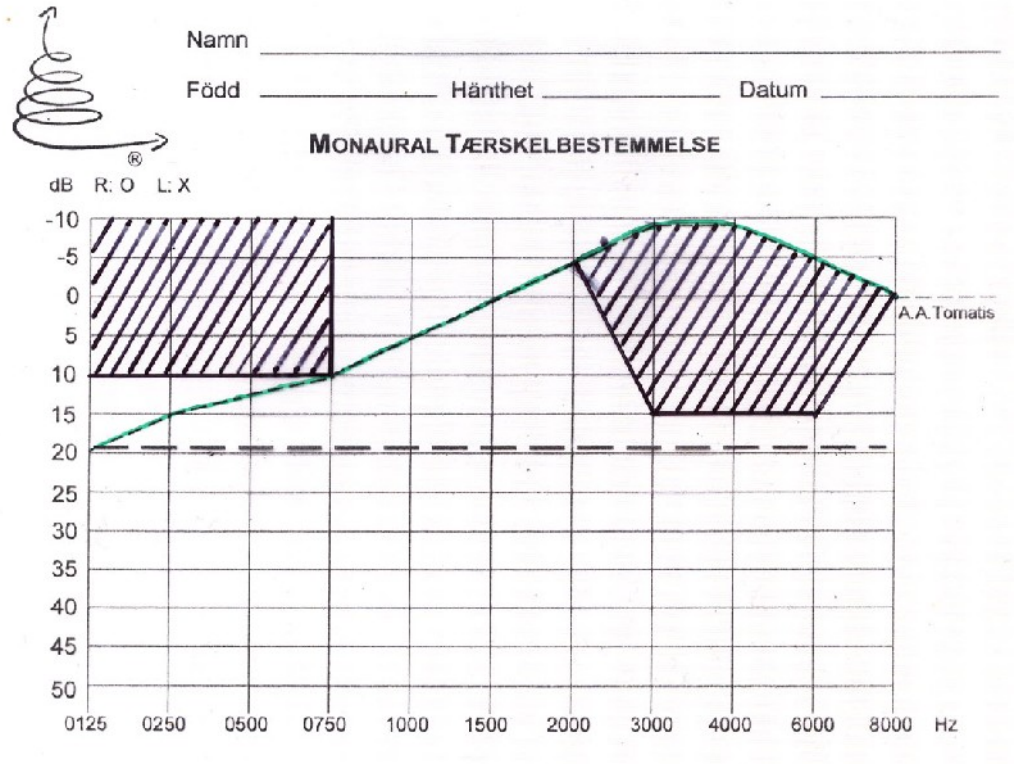


Picture 13. Adam 8 years old, before training.

Although his dip at 6000 Hz is well below the medical praxis-line of 20 dB, most probably, a physician usually doesn't see any medical problems in connection to such a dip.
Children with a dip in the area of 6.000 Hz can't cope with demands connected to time. This means that they have difficulties in succeeding on tests which have a time limit, although they know their home work when leaving home. They can't hurry and often they are the last ones to reach the school-yard at breaks.

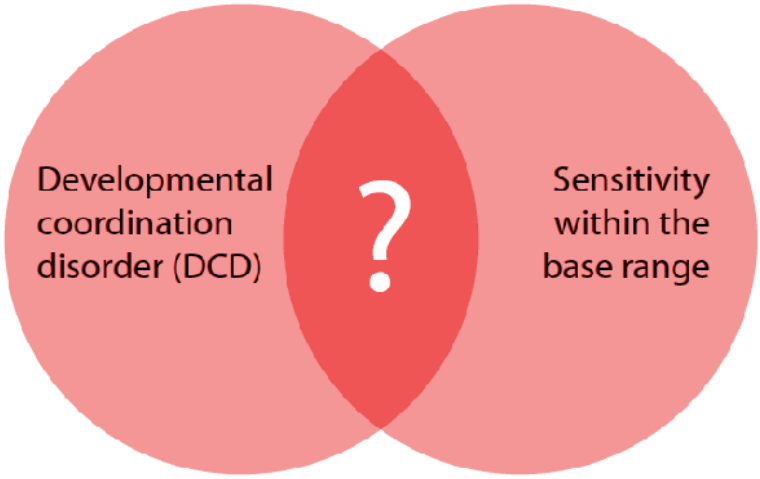
Some might shut out the environment for protection which might be seen as provocative by others. Some might even develop tinnitus or tinnitus alike symptoms and a stress related tinnitus tone is empirically measured to be found in the area around 6.000 Hz.

The second hypothesis, sensitivity at 6.000 Hz is increasing, was not confirmed. Both groups (see picture 7) showed a slight decrease, in age group 7 – 11, 85 % - 83 % and in the group of adults, 88 % - 85 %. Though there is a decrease, the figures are still very high which calls for awareness especially among teachers who runs tests by the clock and who have high demands on children who can't cope.
Worth mention is that those who had a dip below 20 dB, the figures in the younger group were 26 % - 29 % and in the adult group 41 % - 52 % which is an increase of 11 % (See picture 7). All together this brings a triple or at least a double problem.
Problems within the treble range have always been frequent amongst clients but as the base range problems are increasing more and more reversed APPs have been assessed.



Picture 14. Base- and treble ranges.

This negative trend is disturbing not the least because it might mirror what is happening with children in the society as a whole. If so, what will the future bring? Concluded so far is, that we have all reasons to be observant.
A second question, 'If so, why do we need to be more observant?, was asked. Part of the answer is already delivered but auditory perception might also be seen from a wider health perspective. Younger clients are mainly to be found among children within the DCD spectrum. Research have shown that these children are more prone to increased risks for coronary-vascular diseases, decreased cardio-respiratory fitness and increased body fat, because of less physical activity (12).
Also, research from WHO connects noise to an increased production of the stress hormones Cortisol and Adrenalin and further to coronary-vascular diseases (13). Too high levels of these stress hormones are also connected to learning difficulties (14).
The picture below shows a double risk for health problems. Children with auditory perceptual problems and DCD might be at double risk for future health problems unless they found and treated. The work towards an acceptance of auditory perceptual testing and training among both children and adults have to continue. Empirically it has been shown that listening to music on custom made CD's can make a difference.



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Picture 15. Double risk for health problems?

To face the future and the problems it brings we have to build bridges between different areas of research and experiences. The children are our future and they do not benefit from us raising walls.

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Appendix

Distribution

Time, Age, Gender and Frequency Range

	125 Hz - 750 Hz	1500 Hz	3000 Hz - 4000 Hz	6000 Hz / 6000 Hz below 20 dB	M+F
age 7 - 11 1995 - 2000	135 119 16	109 81 28	290 235 55	292 235 57 76 63 13	342 279 63
age 7 - 11 2001 - 2007	177 135 42	98 68 30	286 199 87	279 198 81 81 57 24	336 239 97
age 19 → 1995 - 2000	36 15 21	31 9 22	60 17 43	63 18 45 26 7 19	72 21 51
age 19 → 2001 - 2007	174 52 122	112 20 92	240 69 171	244 68 176 126 40 86	287 79 208

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Picture 16. Distribution; Time, Age, Gender and Frequency Range.

Distribution

male / female in per cent (%)

Period 1 1995 - 2000			Period 2 2001 - 2007		
Age	M	F	Age	M	F
→ 6	83	17	→ 6	70	30
7 - 11	82	18	7 - 11	71	29
12 - 18	74	26	12 - 18	62	38
19 →	29	71	19 →	28	72

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Picture 17. Distribution; Male / Female in per cent (%).

Age	M + F	M	F	M + F
→ 6	29	15	3	18 62%
7 - 11	129	66	17	83 64%
12 - 18	54	17	11	28 52%
19 →	140	25	75	100 71%
	352	123	106	229 65%

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Picture 18. Total amount of clients (at Vestibularis and at Providers) with deviations defined as sensitivity within the base range, 125 Hz – 750 Hz 2005 – 2007.