Evaluating outcome of auditory training

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Various articles suggest that better speech understanding can be obtained by auditory training. Auditory training typically consists of training speech perception in varying background noise levels or with degraded speech signals. Recently a Danish material for auditory training has been developed. This material consists of music training examples as well as speech training exercises. The rationale behind adding music training is variation in exercises as well as calling attention to details in auditory perception that could be valuable in speech perception as well as in hearing aid fitting. The results presented in this poster originate from examination of the benefits this material can provide on speech perception. Results from the investigation show an average benefit of auditory training, but with a large interpersonal variation, suggesting that a preselection of the individuals better suited for auditory training is needed. A battery of cognitive tests has been applied pre- and post-training, results from these tests are presented and discussed, in order to determine if there is correlation between cognition in general, improvement in cognition by auditory training, and obtaining better speech understanding by auditory training.

HISTORY OF AUDITORY TRAINING

Auditory training links naturally to hearing rehabilitation. The attention to the field grew in the USA around World War II, where better diagnostic capabilities and means of rehabilitation of hearing casualties from military service was severely needed. Skills such as lip-reading and “listening practice” would accompany the prescription of hearing aids to minimize the perceived handicap of the hearing loss. As hearing aids were improved during the eighties the auditory training as a unique part of the rehabilitation disappeared. In the late nineties, however, auditory training in the USA had a revival based on computer controlled learning programs and new scientific results.

The basic concept, which makes the training of hearing possible, is the auditory plasticity; reorganizing neural connections in the brain on the basis of input – and behavioural changes (Musiek, 2002). The argument is that a ski-sloping hearing loss, for example, deprives the stimulation of sound at high frequencies, thus causing the neurons to reorganize based on a bass dominated input. Restoring the treble by

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means of a hearing aid will not find the right path in the brain until the connections regarding treble input are restored. Training might improve the speed of these changes.

COGNITION AND HEARING

Sweetow and Henderson Sabes (2004) have introduced a hierarchical communication model illustrating the build-up of acoustical communication from access to sound up to deriving meaningful information through the communication. The model shown below is a slightly modified version of the original (Sweetow and Henderson Sabes, 2004).

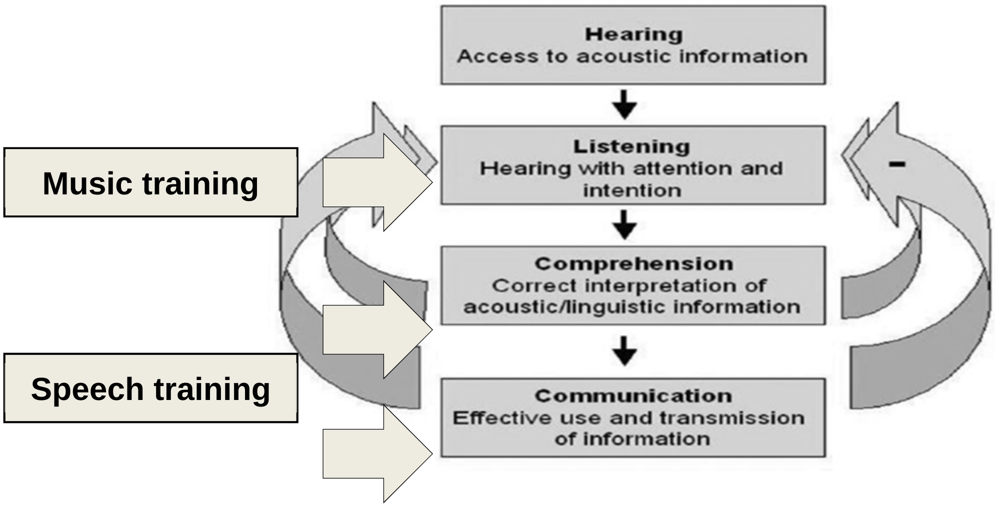


Fig. 1: Hierarchical model of communication form Sweetow and Henderson Sabes (2004), modified with indications of proposed entrance levels for speech and music training (Kristensen, 2013).

Taking this hierarchy into account, it is fair to propose that auditory training with speech signals aims at promoting the understanding at the higher levels in the hierarchy, while music training could be introduced as a way to sharpen the attention of details in the sound signal, as well as a break from speech perception tasks.
It could also be argued that the music training helps to establish connections between listening cues and words describing them, thus enhancing the ability to describe the performance of the hearing aid. This could help in the process of the best possible adjustment of the hearing aid.

In 2007 the Auditory Cognitive Neuroscience Society was founded, acknowledging the need for more multidisciplinary research in cognition and hearing. Cognition represents the mental processes and skills of requiring knowledge. The most prominent cognitive functions are: memory (including working memory), attention, executive functions (self-regulating functions), language functions and floating memory (the genetic preconditions for learning) (Banich, 2004). In acoustical communication these functions enhance our ability to extract the meaning of an acoustical signal in complex listening situations, and thus play an important role in speech perception, as indicated in Fig. 1. Despite the research in the area, so far a clear identification of the cognitive functions most relevant for listening in complex situation has not yet been revealed (Arlinger *et al.*, 2009).

TRAINING MATERIAL

The training material used for this project is based upon a Danish training material designed with speech perception tasks and music listening tasks. The speech part of the material is based upon the Danish DAT speech material. The user task is to identify the two last words of a sentence in the noise of one or two competing sentences. In the user screen it is possible to vary the signal to noise ratio from −10 to +10 dB. A few speech tests with variable speech speed are also found in the material. In the music tasks the user is presented for original as well as degraded music. The user must range the music pieces as more or less degraded (distortion, vibration, and tone) (Kristensen, 2013). In the original training material, the idea of the music listening tasks was to introduce the user to expressions describing sound. In this project the music tasks are only used for variation.

The training material is presented in PowerPoint, which eases the access to systems it can run on but limits the user interaction considerably. Based upon the feedback from the participants in this project it can be concluded to be problematic that only very limited feedback can be given to the user and that it is impossible to adaptively adjust the difficulty for the user.

TEST SET-UP

The current project has investigated if auditory training of hearing aid users has any effect on speech intelligibility in noise, cognitive abilities, communication skills, and degree of hearing handicap in hearing aid users.

Furthermore, it is investigated whether some people benefit more from the auditory training than others do and if so, which factors and personal characteristics can be used to identify those individuals most likely to benefit from auditory training.

To evaluate the effect of the auditory training program, a quantitative experimental study was performed. A participant group of 15 hearing aid users aged 55-81 years was selected to train with the program for two months. Their hearing loss had an average PTA of 55 dB HL varying from 5 dB HL to 95 dB HL. Their discrimination score was on average 74%, varying from 100% to 32%. The inclusion criteria were somewhat loose, as the focus was to recruit as many participants as possible willing to do the training for two months. By coincidence all participants wore different hearing aids. The hearing aids worn by the participants were coincidentally all different newer products from the leading European manufacturers.

Prior to and after the period of training the participant group was presented with a test battery to assess the benefit of the exercises. The test battery consists of both objective and subjective tests in areas where improvement due to the auditory training could be expected. Only off-task tests were selected to reveal a more general effect of the training rather than a learning effect.

Cognitive test	Test modality	Measured cognitive ability
Visual forward digital span test	Visual	Working memory
Jaeggi-Bushkuehl dual n-back task	Audiovisual	Working memory and floating intelligence
Fast counting test	Visual	Visual perception
Go/no-go auditory reaction time test	Auditory	Auditory attention and processing efficiency
Eriksen flanker test	Visual	Information processing and selective attention

Table 1: Overview of the selected cognitive tests, their modality and which cognitive ability they measure.

The test battery consisted of two speech in noise tests – Dantale II and Just Follow Conversation (JFC) – five cognitive tests, and two subjective tests – the NSH question-naire and the Hearing Handicap Inventory for the Elderly (HHIE).

The choice of cognitive tests for this project was not straight forward. First of all the tests had to be in Danish, it should not require skilled personnel (psychologist or equivalent) to perform them, and they should be available at a reasonable price. The cognitive tests in this project were selected from a website (www.cognitivefun.com) which contains a large collection of cognitive tests, testing different functions of cognition. Here it was possible to choose five different tests each focusing on different abilities. The chosen cognitive tests, their test modalities, and the cognitive skills tested in each test, are shown in Table 1.

RESULTS

The results from the pre- and post- speech tests have been summarized in Figs. 2 to 5, showing the difference score for each participant. Bars above the horizontal line indicate improvement from the training, bars below the line indicates that the participant did worse in the post-test. The bar isolated at the right is the average.

The graph for Dantale II (Fig. 2) shows an improvement for roughly half of the participants, and a small set-back or no improvement for the other half. In the JFC case (Fig. 3), all improved or did at least as good in the post-test as in the pre-test. The improvement is significant for JFC (paired *t*-test, p=0.001) but not for Dantale II (paired *t*-test, p=0.051). A fair correlation between the improvement in the two tests for the participants is seen. This indicates improved speech perception for some of the participants. However the test-retest variation of the Dantale II test might be too high to track the small improvements.

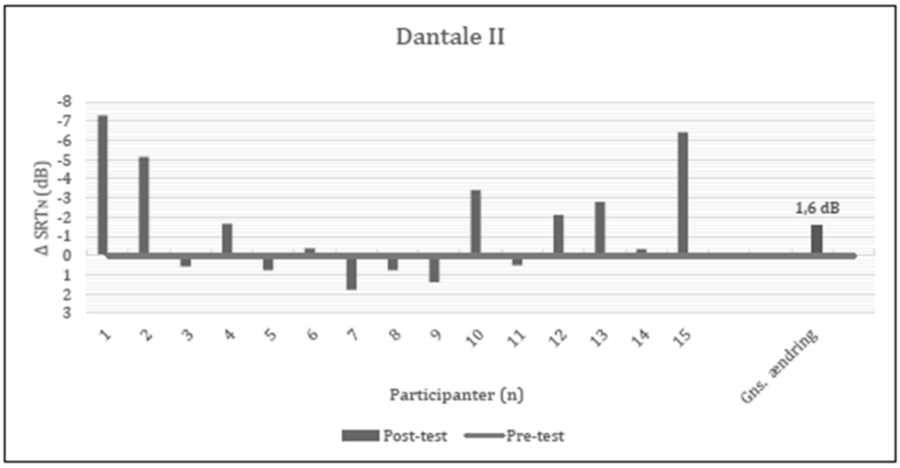


Fig. 2: Improvement per participant and on average ("Gns. ændring", isolated at the right), measured by the Dantale II (Hagermann) speech test.

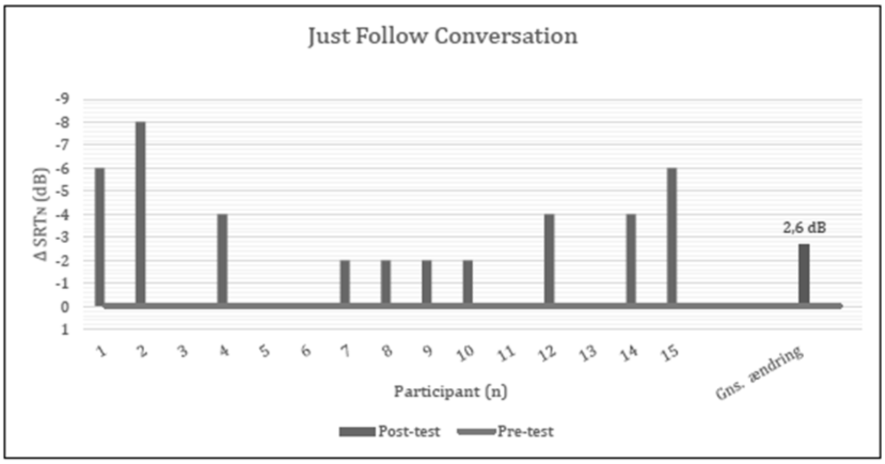


Fig. 3: Improvement per participant and on average ("Gns. ændring", isolated at the right), measured by the JFC speech test.

The graphs for the difference between the pre- and post- answers from the two questionnaires are shown in Fig. 4. In the NSH questionnaire a majority of participants indicate very little effect from the training. No significant improvement could be found. (paired *t*-test, p=0.255). The HHIE shows a significant average improvement (paired *t*-test, p=0.019). Further analysis reveals that improvement primarily origins from situational rather than emotional questions of the HHIE.

Graphs representing the cognitive tests are shown in Fig. 5. Both tests show steady or improved performance for the majority of participants.

Looking at the general results from the test battery, an improvement due to auditory training seems to be plausible. The improvement is most clearly visible in the JFC speech test, in the situational questions of the HHIE, and in some of the cognitive tests. From the tests it is also clear that some participants seem to benefit more from the training than others, with different participants showing improvement in different tests. Thus it is difficult to find a clear pattern of which participants in general improved in the tasks trained in the test battery. A hint to which factors and personal characteristics can be used to identify those individuals can be derived from a correlation analysis (Pearson's correlation coefficient). Table 2 presents a matrix of the Pearson corrrelation of the improvement of variables with demographic factors and pre-test scores. It indicates that tone loss and years with hearing loss correlate with improvement in the go/no go auditory test. As the go/no-go auditory test is testing auditory attention and processing efficacy, it is fair to speculate that people with larger and longer lasting hearing losses will benefit from the training because it sharpens their auditory attention.

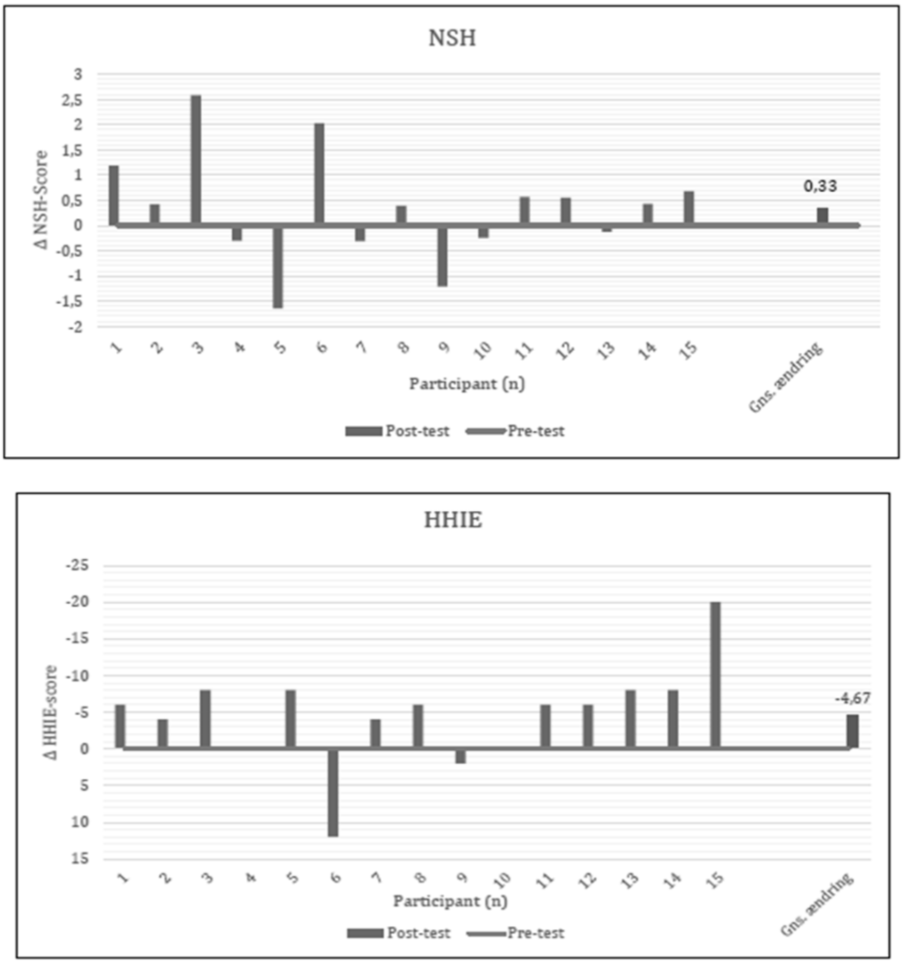
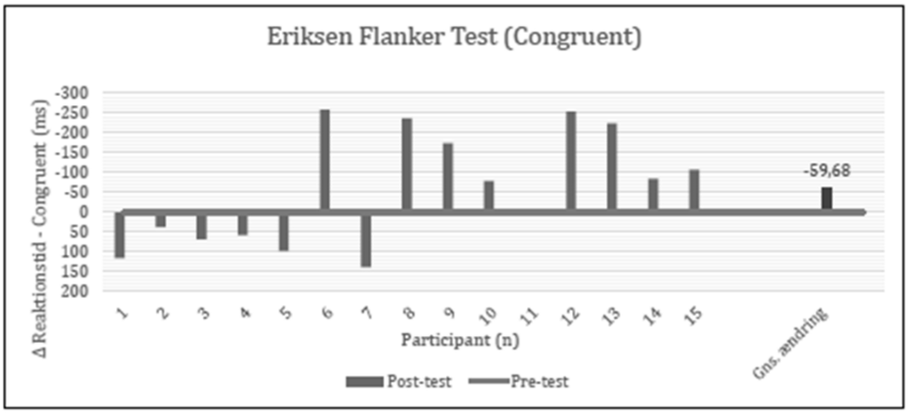


Fig. 4: Improvement per participant and on average ("Gns. ændring", isolated at the right), measured by the NSH (top panel) and the HHIE (bottom panel) questionnaires.



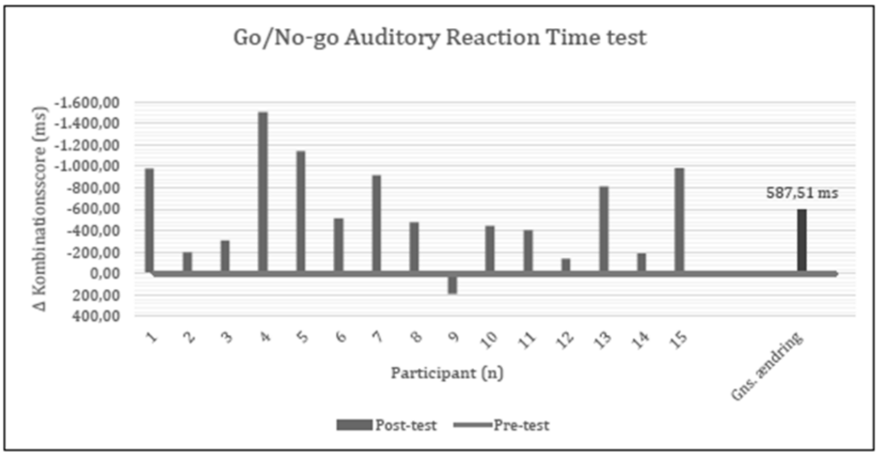


Fig. 5: Improvement per participant and on average ("Gns. ændring", isolated at the right), measured by two of the cognitive tests. These figures were selected for this article as the correlation analysis indicates that improvement in these cognitive tests correlates with severity of hearing loss and Dantale II score.

The table also shows that discrimination score correlates with the congruent part of the Eriksen flanker test. The cognitive ability tested in this test is information processing and selective attention, which again indicates that auditory training enhances attention and processing speed, and the more pronounced the hearing loss the more benefit.

It is also interesting to note that age and hours of training do not seem to influence the measured benefit of the training. If the latter is true it calls for a much more adaptive approach to the training than the current Danish training material at present can offer.

CONCLUSION

From the feedback from the participants it is clear that the training material should have a more adaptive difficulty level and should provide more feedback. The use of music tasks is a good variation of the training. From the questionnaires answered it seems that the training has only limited influence on the participants' perceived improvement from the training.

The results from this project indicate that auditory training can improve cognitive skills related to speech understanding and performance in speech tests. However, the benefit of the training varies considerably among the participants. Correlation analysis hints that more severe, longer lasting hearing losses undergo the biggest improvement in auditory attention and information processing ability from the training.

		Improvement in dependent variables (from pre to post test)									
		Dantale II (SRT_N)	JFC (SRT_N)	Go/No-go Auditory test	Fast Counting	Eriksen Flanker test (Congurent)	Eriksen Flanker test (Incongurent)	Jaeggi-Buschkuel	Visual digit span	NSH Questio-narie	HHIE
Demographics and variables pretest score	Age	0,31	0,09	-0,18	-0,06	0,26	0,18	0,12	-0,14	0,35	0,18
	Tone-loss	-0,17	-0,13	0,55*	-0,19	-0,33	-0,23	0,01	0,08	0,16	-0,1
	Discrimination Score	0,08	-0,03	0,5	0,2	0,56*	0,41	-0,18	0,09	0,08	0,17
	Years with hearing loss	0,04	0,04	0,73***	-0,1	-0,32	-0,31	-0,39	-0,18	0,08	0,09
	Years with hearing aids	-0,04	-0,2	0,29	0,06	-0,12	0,09	-0,03	0,25	0,48	-0,28
	Hours of auditory training	0,38	0,41	0,5	0,11	-0,22	-0,15	-0,46	0,14	0,22	0,1
	Dantale II (SRT_N)	-0,04	0,05	0,55*	-0,37	-0,55*	-0,42	-0,13	-0,04	0,13	-0,31
	JFC (SRT_N)	-0,29	0,07	0,42	-0,36	-0,49	-0,3	0,08	-0,35	-0,16	-0,32
	Go/No-go Auditory test	0,16	-0,07	0,9	-0,01	-0,31	-0,52	-0,21	-0,07	-0,32	0,28
	Fast Counting	0,01	0,01	0,49	-0,45	-0,46	0.59*	0,16	0,16	-0,28	-0,16
	Eriksen Flanker test (Congurent)	-0,2	-0,06	-0,32	0,13	0,76***	0,61**	0,11	0,21	-0,11	0,14
	Eriksen Flanker test (Incongurent)	-0,35	-0,16	-0,44	0,09	0.78***	0,78***	0,06	0,19	0,01	-0,09
	Jaeggi-Buschkuel	0,18	-0,25	-0,13	0,21	-0,01	0	-0,3	0,52*	0,53*	0,03
	Visual digit span	-0,21	-0,23	-0,09	-0,16	-0,64**	-0,37	0,27	-0,47	0,01	-0,07
	NSH Questionarie	-0,13	-0,29	-0,22	0,25	0,19	0,07	0,21	0,27	-0,49	-0,06
	HHIE	0,05	0,39	0,32	-0,07	-0,44	-0,35	0,1	-0,11	-0,35	0,36

Table 2: Pearson's correlation matrix between demographic data and pre-test score of dependent variables with improvements of dependent variables. Circles show significant correlations between variables. Correlations between pre-test score and improvement for the same variable are not highlighted.

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