The TFS1-test reveals mild hearing loss

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Introduction

Growing evidence suggests that hearing-impaired listeners are much less able to extract information from the temporal fine structure (TFS) of a sound signal than normal hearing listeners (Hopkins et al., 2008; Santurette and Dau, 2006). This is in surprising contrast to the ability to make use of the temporal envelope of the sound, which seems to be relatively well preserved in hearing-impaired listeners. One way to better understand the TFS phenomenon would be to investigate possible correlations between individual variations in a clinical psychoacoustic TFS test and the real-world consequences that a hearing-impairment may cause. If such a correlation was found, an important link between TFS deficits and real-world problems would be established.

The current study investigates the usefulness of the TFS1-test (Moore and Sek, 2009) as a diagnostic tool by comparing the results from hearing impaired (HI) and normal hearing (NH) listeners.

Experiment 1

Participants

Subjects included 19 listeners with mild to moderate hearing loss. Subjects ranged from 30 to 82 years, with a mean age of 62 years. Air-bone gaps were 15 dB or less and tympanograms were normal. The HI listeners showed no dead regions, as assessed using the 'TEN HL' test (Moore et al., 2004).

Furthermore, 8 listeners with normal hearing were included, aged from 26 to 43 years, with a mean age of 36 years. The NH listeners had hearing thresholds of 20 dB or below and no history of hearing problems.

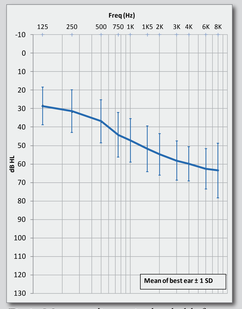

Fig.1. Mean audiometric thresholds for the 19 hearing impaired listeners

TFS1 test

Listeners discriminated harmonic and frequency shifted tones. The phases of the components were selected randomly for every stimulus. Both complexes had an envelope repetition rate equal to F0, but differed in their TFS. To prevent discrimination based on spectral cues, all tones were passed through a fixed band pass filter. A background noise was used to mask combination tones (Moore & Sek, 2009). The stimuli were presented over headphones to the best ear.

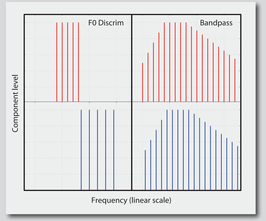

Fig.2. Representation of test stimuli. The left column shows stimuli used for a F0 discrimination task. The right column shows harmonic and frequency shifted tones which have a similar envelope repetition rate but different TFS

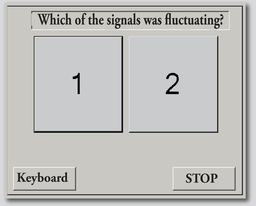

Fig.3. User interface of the TFS1 test

Fig.4. Stimulus duration and inter-stimulus interval for the TFS1 test

Conditions

Condition	Description	Cues
F0	F0 is changed Task training	**Place cue** plus **differences in TFS** and **differences in envelope**
N5	Bandpass filtered at the 5th harmonic Task training	Resolved for NH and most HI; therefore **place cue** and **differences in TFS**
N11	Bandpass filtered at the 11th harmonic Test condition	Believed to be unresolved; stimuli have NO place cue, but only **differences in TFS**

Results experiment 1

The task training conditions F0 and N5 showed that the test procedure was well understood by both NH and HI listeners, as reliable thresholds were obtained in most – if not all – cases. For the N11 test conditions, the TFS1 test measured the degree of sensitivity to TFS for NH listeners only; it was very difficult or impossible to get reliable TFS1 thresholds for any of the HI listeners in the test conditions (N11). This suggests that the HI listeners either had no TFS abilities left above 1 kHz or that the test was not sensitive enough. It was concluded that the test needed further development in order to measure the degree of remaining TFS-abilities among the HI listeners.

Experiment 1

	F0	N5			N11		
F_c	500	500	1000	2000	1100	2200	4400
HI1	7.8	50%	31.6	25%	40%	45%	25%
HI2	3.6	37.1	9.7	142	45%	55%	50%
HI3	3.4	65%	60%	40%	35%	65%	30%
HI4	2.5	26.6	9.7	8.5	45%	45%	40%
HI5	22.9	50%	60%	36.1	50%	65%	55%
HI6	14.1	25%	34.0	50%	45%	50%	60%
HI7	6.5	9.4	27.2	45%	25%	50%	45%
HI8	5.2	33.2	46.9		40%	80.0	55%
HI9	1.8	8.4	13.4	34.8	55%	60%	91.6
HI10	5.4	60%	9.0	75%	60%	71.6	40%
HI11	4.5	35%	80%	51.2	50%	40%	55%
HI12	7.2	8.7	15.0	16.6	65%	40%	55%
HI13	4.5	13.6	4.6	13.2	30%	21.8	65%
HI14	4.5	50%	15.6	57.2	55%	65%	60%
HI15	4.8	50%	45.8	80%	50%	50%	55%
HI16	3.6	2.2	5.3	33.6	55%	40%	55%
HI17	8.7	65%	23.4	45.2	37.1	35%	55%
HI18	7.0	50%	24.3	106	65%	50%	55%
HI19	1.7	45%	9.6	34.8	20.5	65%	45%
NH1	1.3	6.0	5.5	3.9	10.9	29.3	65.5
NH2	1.7	5.2	3.3	22.3	11.3	8.0	41.9
NH3	1.6	5.0	8.3	9.1	9.4	95%	37.5
NH4	0.7	4.6	3.4	9.1	15.2	4.4	10.2
NH5	1.9	13.1	5.9	17.4	32.0	23.4	60%
NH6	2.9	6	8.9	9.3	11.7	13.4	46.4
NH7	1.5	5.6	10.0	10.6	10.9	17.4	46.9
NH8	3.6	30.8	16.8	14.8	24.7	21.0	78.9

Experiment 2

	N11
F_c	1100
HI10	38%
HI11	40%
HI12	43%
HI13	48%
HI14	55%
HI15	58%
HI16	58%
HI17	60%
HI18	60%
HI19	60%
NH5	60%
NH6	5.8
NH7	9.4
NH8	20.5
NH9	34.5

Longer stimuli Increased exposure More trials

All HI failed!

Binary result

TFS1-test useful as screening tool?

Fig.5. Results experiment 1 (left) and experiment 2 (right). Green indicates thresholds obtained. Chance performance is indicated in red: for experiment 1 up to 80%, for experiment 2 up to 70% correct. F0 and N5 conditions were used for task training.

Experiment 2

Participants

Experiment 2 used a subset of 10 HI and 4 NH subjects of experiment 1. An additional NH subject with the same criteria was also included.

TFS1.5 test stimuli

Kathryn Hopkins at Cambridge University developed a newer version of the TFS1 test with prolonged stimuli. Moreover, the number of trials was increased from 20 to 40 when maximum possible frequency shift in the stimuli was reached, enhancing the power of the test.

Fig.5. Stimulus duration and inter-stimulus interval for the TFS1.5 test

Results experiment 2

For most NH listeners a threshold was obtained.
All HI listeners failed the test.

Discussion and conclusion

- On both the TFS1 and the TFS1.5 test, a rather binary result was found: for most NH listeners, the test measured the degree of sensitivity to TFS. Most HI listeners, on the other hand, scored no better than chance.
- It seems that if a listener has a hearing impairment severe enough to benefit from a hearing aid -all subjects tested were hearing aid users - then a failure on the TFS1 and TFS1.5 test is predicted. These findings are in line with other experiments showing that elevated audiometric thresholds have a severe impact on sensitivity to TFS as measured with similar stimuli (Anderson et al., 2010; Hopkins et al., 2010).
- The TFS1 test may not be useful as a clinical tool to find individual variations in TFS sensitivity for HI listeners.
- However, the TFS1 test may have potential as a screening tool for mild to moderate hearing loss, which may be quicker and easier to administrate than an audiogram.
- Further research is needed to establish whether the TFS1 test can distinguish between NH and even milder hearing loss than included in the current study.

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