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INVESTIGATIONS INTO SPEECH INTELLIGIBILITY IN THE PRESENCE OF DIFFERENT MASKING NOISES FOR HEARING AIDS WITH VARIABLE ATTACK AND RELEASE TIMES

E. HOJAN[1], H. FASTL[2], J. MALENDA[1]
D. HOJAN–JEZIERSKA[3]

[1)] Adam Mickiewicz University
Institute of Acoustics
Umultowska 85, 61-614 Poznań, Poland

[2)] TU Munich
Chair for Man-Machine-Communication, Germany

[3)] Medical Academy of Poznań
Chair of Biophysics, Poland

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People with hearing impairments experience a reduction in speech intelligibility in noisy surroundings. The extent of this reduction depends on the degree of impairment in the temporal resolution of the patient's ear, too.

The change of the speech intelligibility of hearing-impaired people was investigated in the presence of different masking noises, especially when using hearing aids with adjustable attack (AT) and release (RT) times within same frequency bands.

Key words: speech intelligibility, masking noises, hearing aids, attack and release times.

1. Introduction

Not only dislocated hearing thresholds have an influence on the patient's speech intelligibility.

Impaired hearing faculties such as frequency discrimination ability, time resolution and integration [6, 10, 14] have a negative influence on patient's speech intelligibility, too. In order to achieve a high speech intelligibility, it is important to ensure that what remains of such hearing faculties is not further diminished by the hearing aid.

Since hearing-impaired people in noisy surroundings complain of difficulties with speech intelligibility which does not occur in quiet surroundings, it would be worthwhile carrying out audiometric tests with speech in the presence of masking noise. Even in

early stages of a hearing loss, the speech intelligibility is already diminished in noisy surroundings [3, 7, 9, 11, 15].

A hearing-aid fitting can only be successful if it is carried out in situations which typically prove critical of speech discrimination, namely in the presence of masking noise.

The masking noises employed in the audiometric tests are CCITT Rec. G. 227 noises or Fastl noise [12].

The speech-simulating CCITT noise has a constant loudness level. The Fastl masking noise shows clear loudness fluctuations corresponding to the frequency of a succession of syllables in human speech. The spectral distribution of the CCITT noises or Fastl noise are identical and, especially at frequencies above 800 Hz, reproduce the spectral distribution of speech [4, 5, 11].

The fluctuating noise suggested by Fastl creates a masking effect in situations (disturbance from one or more speakers) corresponding to everyday situations: "competing speech" and "cocktail party" which are to be simulated. By means of temporal fluctuations of 4 Hz it is possible to test the ability of signals listening in gaps of masking noise as a measure of an intact temporal functionality of the ear. A speech/noise ratio of –9 dB already suffices for 50% speech intelligibility by Fastl noise compared to –2 dB by constant CCITT noise for normal-hearing subjects [11]. Reference data for Fastl noise have already been published for normal-hearing subjects [5, 7].

The specific adjustment and control options offered by the hearing aid are decisive for individual adjustment to the patient's hearing ability.

It is possible to limit the maximum output sound level (PC = Peak Clipping), to compensate partly for a frequency-dependent hearing loss by means of tone controls, or to adjust the gain of the hearing aid to the patient's compressed dynamic range with AGC circuits [1, 2, 8].

Because of these adjustment and control circuits, hearing instruments have different attack and release times, which can also be employed to influence the speech intelligibility in hearing-aid wearers both positively and negatively. Different times have been considered appropriately in the reference literature [2, 10].

The study presented here was aimed at the investigation of influences of the attack and release times of hearing aids on the speech intelligibility by hearing impaired people in the presence of various masking noises.

2. Experiments

Two experiments are presented for two word tests, the first one with German and second one with Polish hearing impairments; both the groups had a bilateral cochlear hearing loss for which the hearing faculties such as frequency discrimination ability, time resolution and integration have negative influence on the patient's speech intelligibility.

Experiment No. 1

2.1. Test subjects

Seven German test subjects (TS 1 to TS 7) aged from 29 to 74 with bilateral cochlear hearing loss participated in the experiments. The hearing loss of these test subjects was between 40 dB and 95 dBHL in the frequency range between 125 Hz and 6000 Hz. The test subjects TS 1 to TS 5 have already been wearing BTE hearing aids for several years. Without hearing aids, they were unable to understand the speech. The TS 6 and TS 7 test subjects did not possess yet a hearing aid.

2.2. Test method

The Freiburg monosyllables word test as per DIN 45621 (speech) and the CCITT Rec. G227 or Fastl masking noises [4–6] (noise), were presented via loudspeakers in free field to the hearing-impaired test subjects without or with hearing aids by the desired speech/noise ratio ΔL. The level of the masking noises (or the associated calibration signals) was 65 dBSPL at the location of the test subjects' ears. The word lists were presented at various levels to provide speech/noise ratios ranging from -2 dB to $+22$ dB.

The Freiburg word lists (groups from 1 to 20), selected at random, were chosen for the tests. The test subjects repeated the words they heard. The test supervisor was able to enter subjects' responses to the computer and to evaluate them by means of computer software especially developed for these tests. The score (h) for the number of words correctly understood was determined in each case.

For three test subjects (TS 3, TS 4, TS 5), the speech discrimination was also determined in the presence of masking noise using hearing aids with adjustable attack (AT) and release (RT) times. The attack and release times by hearing aids used in the experiments were varied from 0 ms to 500 ms (AT) or from 0 ms to 150 ms (RT). The gain curve of the hearing aids with variable attack and release times was adjusted to the gain curve of the hearing aid worn by the patient and the speech/noise ratio corresponding to a speech intelligibility of $h = 50\%$ selected for the subject's own hearing aid.

2.3. Results

The speech intelligibility with CCITT Rec. G227 or Fastl masking noise was determined for all seven hearing-impaired subjects as illustrated in Figs. 1 and 2.

Figure 1 shows data for hearing-impaired subjects with a hearing aid (TS 1–TS 5). The data from Fig. 2 are for hearing-impaired subjects without any hearing aid. The latter group was merely a control group as these subjects conform to the data found in the reference literature [11].

The curves depicted in Fig. 1 show a clear discontinuity. However, it is identifiable that on the average, at h = 50% (see Table 1) there are differences of only about 3 dB in the speech/noise ratio between the two masking noises for hearing-aid wearers.

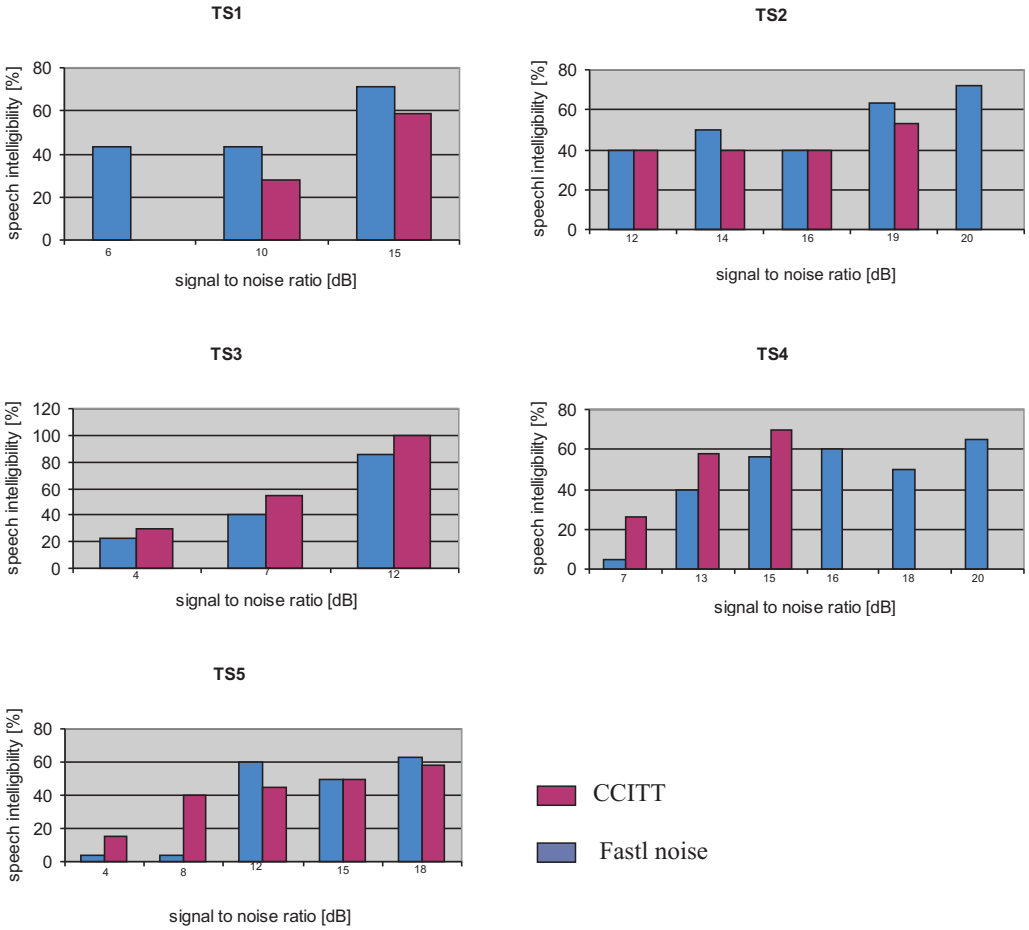
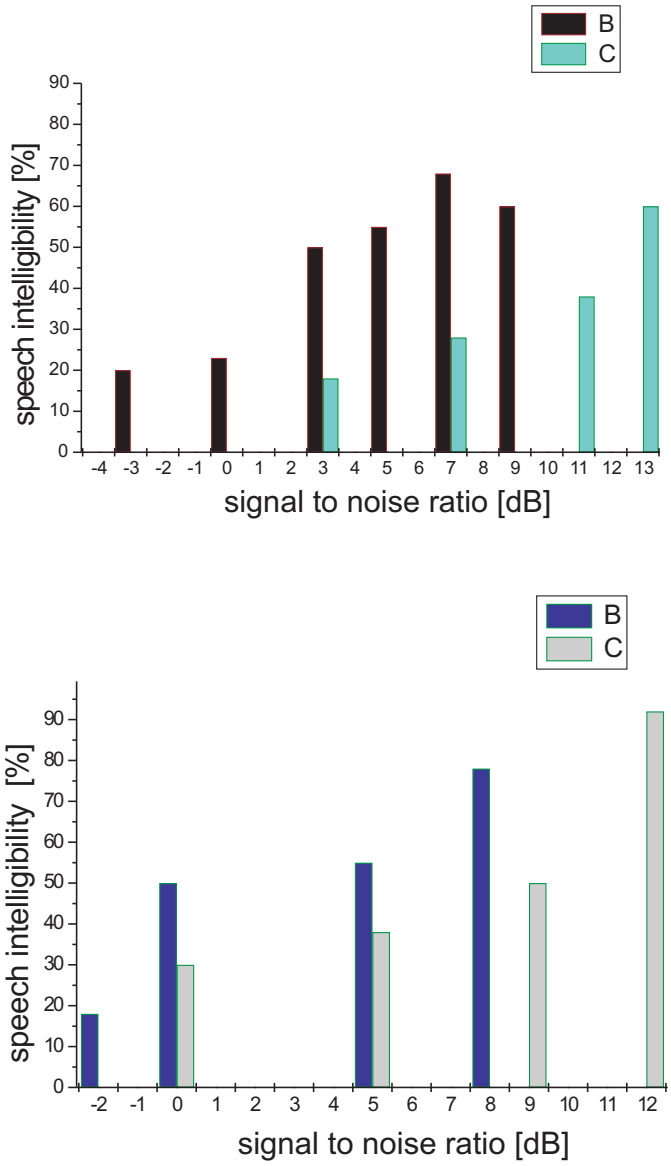


Fig. 1. Scores for monosyllables in the respective masking noise as a function of speech to noise ratio ΔL for 5 hearing impaired (TS1 to TS5) with their hearing instruments. Circles: Fastl noise; Square: CCITT G. 227 noise.

The hearing aids worn have all defined attack and release times of control circuits (see Table 2). The hearing aids of test subjects TS 1 and TS 2 had no AGC circuits.

Figure 2 shows that for hearing-impaired people without hearing aids there are differences up to 9 dB in the speech/noise ratio for the 50% speech intelligibility between the CCITT and Fastl masking noise. Evidently hearing-impaired listeners without a hearing aid can "listen in" to the gaps in the Fastl noise at least to some extent. The hearing-impaired subjects with hearing aids examined in this pilot study have apparently lost this ability.

If one compares the speech/noise ratios ΔL achieved by the group of test subjects with hearing aids with those without hearing aids in the presence of the same masking



B – Fastl noise

C – CCITT noise

Fig. 2. Scores for monosyllables in the respective masking noise as a function of speech to noise ratio ΔL for 2 hearing impaired (TS6, TS7) without hearing instruments. Circles: Fastl noise. Square: CCITT G. 227 noise.

Table 1. Speech/noise ratio ΔL for hearing-impaired subjects for the speech intelligibility of h = 50% of correctly understood monosyllables for CCITT or Fastl noise.

	ΔL [dB]			
	Without hearing aid		With hearing aid	
	Type of masking noise		Type of masking noise	
S	CCITT	Fastl	CCITT	Fastl
1			+14	+11
2			+18	+15
3			+ 8	+ 9
4			+15	+12
5			+12	+14
6	+11	+2		
7	+ 9	±0		
Median	+10	+1	+14	+12

Table 2. Attack – (AT) and release-times (RT) of the hearing instruments of 3 subjects (TS 3, TS 4, TS 5); attack – (AT) and release-times (RT) of the hearing aids are constant.

	AT	RT
TS 3	5 ms	250 ms
TS 4	9 ms	110 ms
TS 5	3 ms	50 ms

noise, then the differences in speech/noise ratio ΔL measured for an equal speech intelligibility h = 50% with a CCITT masking noise are relatively minor at 4 dB for all hearing-impaired subjects. With the Fastl noise however, the differences between the groups with and without hearing aids are 11 dB, i.e., there is clear evidence that at a fluctuating masking noise the temporal processing of the hearing aid has an influence on the speech discrimination.

In order to record this influence, the speech intelligibility was determined also for three hearing-impaired subjects, TS 3, TS 4 and TS 5, for both the masking noises (CCITT and Fastl) using hearing aids with adjustable attack and release times based on the speech/noise ratio for a 50% speech intelligibility (Table 3).

For the hearing-impaired subject TS 3 (used hearing aid – attack time AT = 9 ms, release time RT = 110 ms), the speech intelligibility h increased for the Fastl noise almost all the time. Only at AT = 0 ms, RT = 7 ms, the speech intelligibility h decreased for the Fastl noise. The subject TS 3 achieved the greatest improvement at AT = 100 ms,

Table 3. Speech intelligibility of $h = 50\%$ correct monosyllables for CCITT or Fastl noise for 3 hearing-impaired subjects (TS 3, TS 4, TS 5; attack- (AT) and release-times (RT) of the hearing aids are adjustable.

Test subject	Cut-off frequency band	AT	RT	Speech intelligibility [%]	
	[Hz]	[ms]	[ms]	CCITT noise	Fastl noise
TS 3	800	0	7	65	40
		0	35	50	70
		0	150	60	80
		20	7	60	75
		20	35	70	70
		20	150	50	65
		100	7	65	75
		100	35	60	85
		100	150	60	70
		500	7	65	70
		500	35	65	75
		500	150	60	75
TS 4	800	0	7	25	10
		0	35	20	20
		0	150	15	15
		20	0	40	25
		20	35	20	45
		20	150	50	45
		100	0	20	25
		100	35	15	30
		100	150	10	30
		500	7	50	30
		500	35	10	25
		500	150	20	30
TS 5	1200	0	7	40	30
		0	35	50	15
		0	150	45	40
		20	0	25	30
		20	35	40	55
		20	150	35	50
		100	0	35	30
		100	35	35	25
		100	150	55	25
		500	7	40	25
		500	35	30	25
		500	150	15	15

RT = 35 ms ($h = 60\%$ for CCITT noise and $h = 85\%$ for Fastl noise). The still relatively intact temporal processing ability of his ear could be exploited by means of a favourable adjustment of the attack and release times of his hearing aid for improved speech discrimination.

The data for the hearing-impaired subjects TS 4 and TS 5 (used hearing aid – attack time AT = 3 ms, release time RT = 50 ms) look very different. For them, the speech intelligibility decreased in many cases.

They hearing aids were in many cases already adjusted optimally for them as regards the attack and release times.

The poor temporal processing ability of their ears could not be compensated by a specific adjustment of the hearing aid.

Experiment No. 2

2.4. Test subjects

In the experiment, 17 Polish test subjects aged from 21 to 89 (TS 1 P.J, TS 2 B.K, TS 3 Ż.K, TS 4 C.B, TS 5 J.J, TS 6 G.H, TS 7 L.J, TS 9 S.Sz, TS 14 J.Sz, TS 15 N.J, TS 16 S.A – with bilateral cochlear hearing losses (Δ conductive (air-bone) $\leq$ 15dB, SISI > 65%), and TS 8 B.J, TS 10 TT, TS 11 S.F, TS 12 H.P, TS 13 W.K, TS 17 C.J – with conductive hearing losses in frequency band to 1kHz and cochlear hearing losses in frequency band up 1 kHz) participated. The hearing loss of these test subjects was between 40 dBHL and 95 dBHL in the frequency range between 125 Hz and 6000 Hz. All test subjects have already been wearing BTE hearing aids for several years.

2.5. The test method

The Polish monosyllables word test from Pruszewicz [13] and Fastl masking noises [4–6] were presented at various levels to provide the speech/noise ratio ΔL = +5, +10 and +15 dB, to the hearing-impaired test subjects without hearing aids via loudspeakers in free field. The groups 1 to 20 of the Polish word test (selected at random) were employed for the tests. The masking noises (or the associated calibration signals) produced a sound level of 65 dBSPL at the location of the test subjects' ears. The score (h) for the number of words correctly understood was determined. Then the other word lists were presented to the same hearing-impaired test subjects with hearing aids (with adjustable attack (AT) and release (RT) times), via loudspeakers, in the same free field, at speech/noise ratios, for which the understanding of speech (without hearing aids) was found to between 35 to 65%. First the gain curve of the hearing aids with variable attack and release times was adjusted to the gain curve of the hearing aid worn by the patient (at the same attack and release times).

The attack and release times of the hearing aids, with adjustable attack (AT) and release (RT) times, were varied in two frequency bands in 5 sessions, Table 4.

Table 4. Variable attack and release times of the hearing aids in Sessions 0 to 5 in two frequency bands.

AT [ms]	AT [ms]	RT [ms]	RT [ms]	
Low band	High band	Low band	High band	Session
10	5	80	320	0
2	1	80	320	1
0	0	80	320	2
10	5	160	160	3
10	5	40	40	4
10	5	640	640	5

2.6. Results

Figure 3 shows the value of speech intelligibility for test subjects with hearing aids, at attack time AT=10 ms and release time RT=80 ms in the low frequency band and AT = 5 ms and RT = 320 ms in the high frequency band; for the subjects TS 4 and TS 8, AT = 10 ms and RT = 320 ms in the low frequency band and AT = 5 ms and RT = 640 ms in the high frequency band (Table 4 – Session 0). All these data for the AT and RT computer software have been chosen.

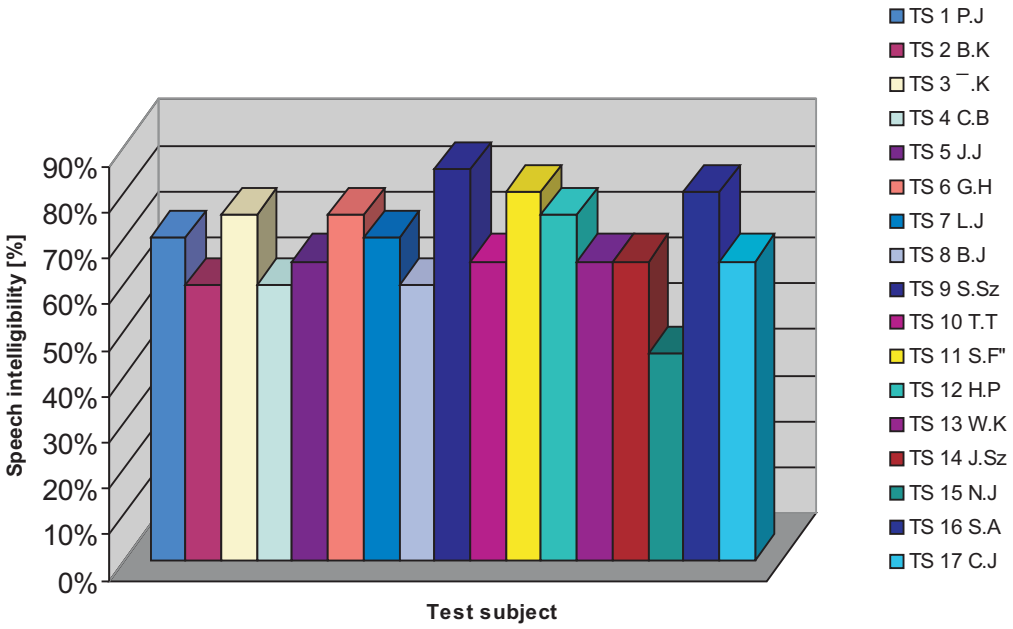


Fig. 3. Scores for monosyllables in the Fastl masking noise for test subjects with hearing aids at adjustable attack (AT) and release (RT) time; Session 0 (see Table 4).

Figures 4 to 8 show the change of the volume of speech intelligibility for test subject with hearing aids by adjustable attack (AT) and release (RT) (Table 4 – Session 1 to 5). The experimenter have chosen all these data for AT and RT .

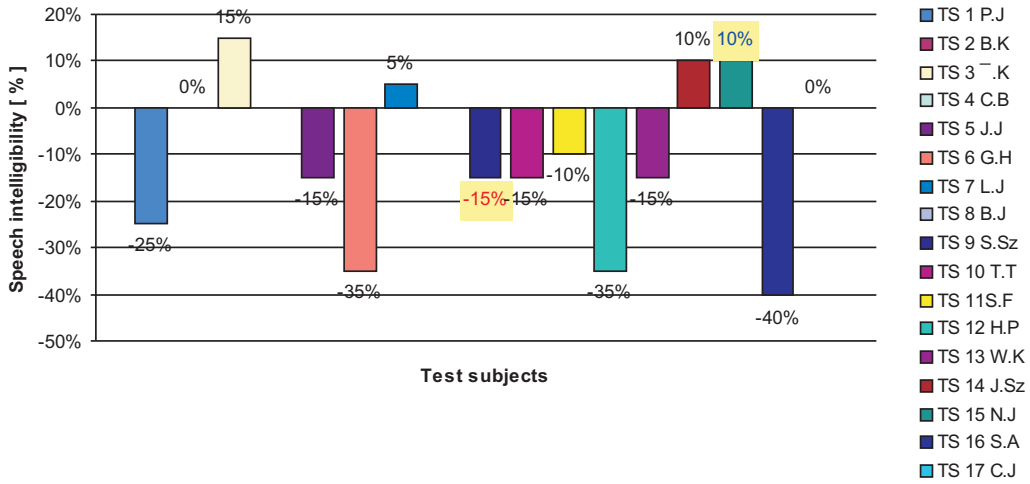


Fig. 4. Scores for monosyllables in the Fastl masking noise for test subjects with hearing aids at adjustable attack (AT) and release (RT) time; Session 1 (see Table 4).

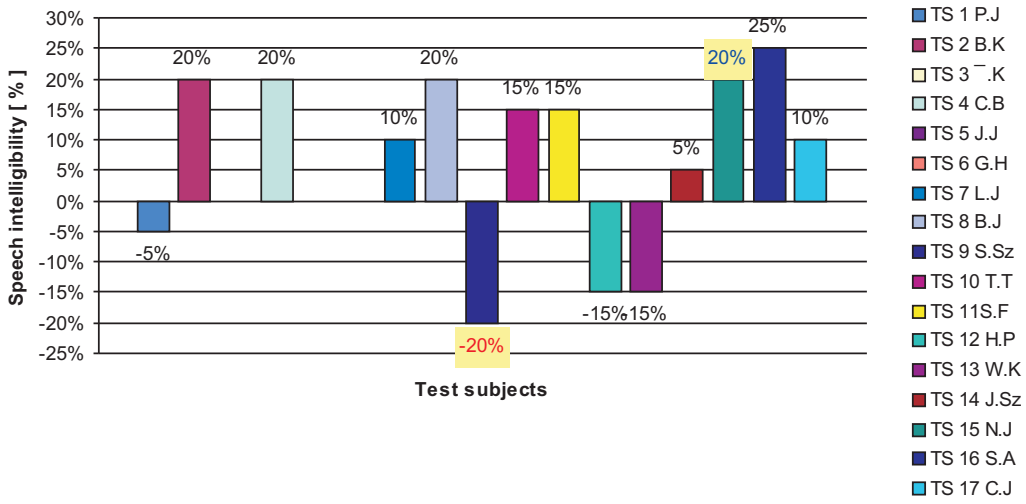


Fig. 5. Scores for monosyllables in the Fastl masking noise for test subjects with hearing aids at adjustable attack (AT) and release (RT) time; Session 2 (see Table 4).

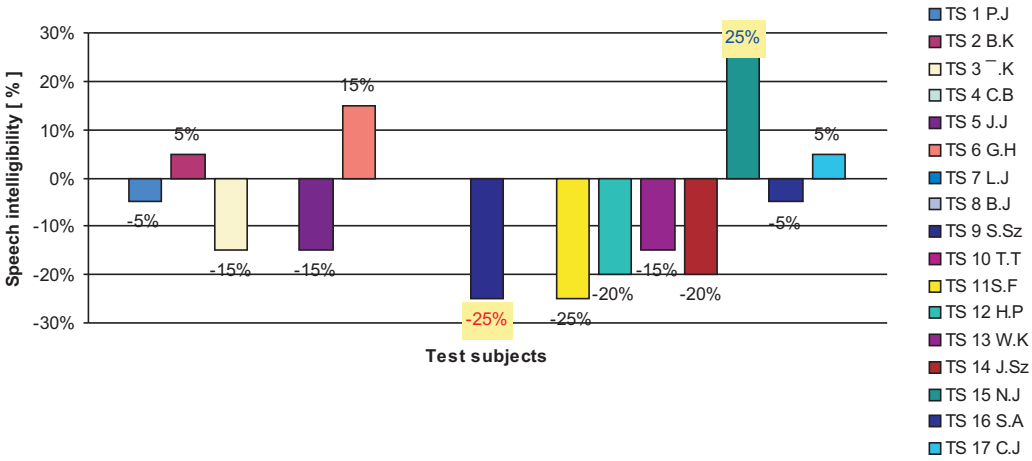


Fig. 6. Scores for monosyllables in the Fastl masking noise for test subjects with hearing aids at adjustable attack (AT) and release (RT) time; Session 3 (see Table 4).

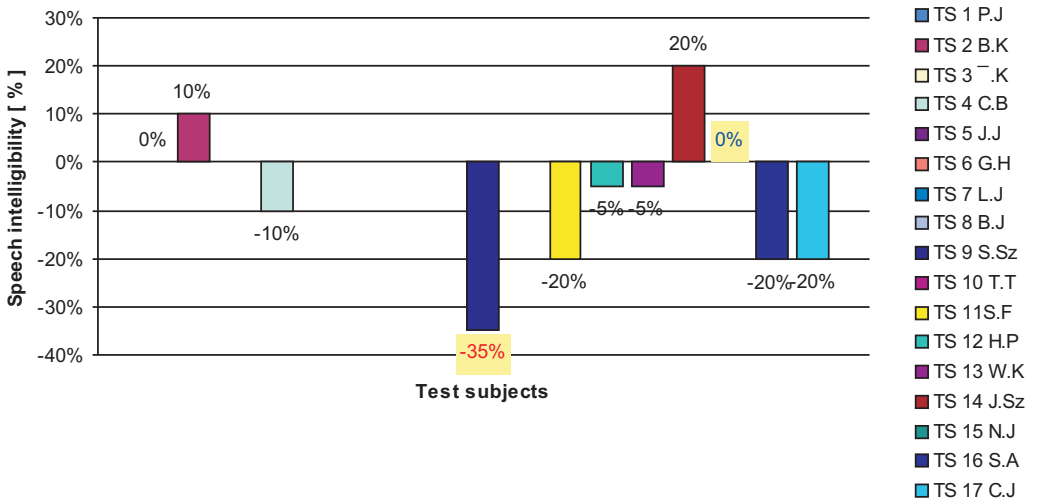


Fig. 7. Scores for monosyllables in the Fastl masking noise for test subjects with hearing aids at adjustable attack (AT) and release (RT) time; Session 4 (see Table 4).

The best improvement of speech intelligibility (for 10 test subjects) were found in Session 2; the largest loss of speech intelligibility (for 11 test subjects) appeared in Session 5. In Sessions 3 and 4 also a loss of speech intelligibility was detected.

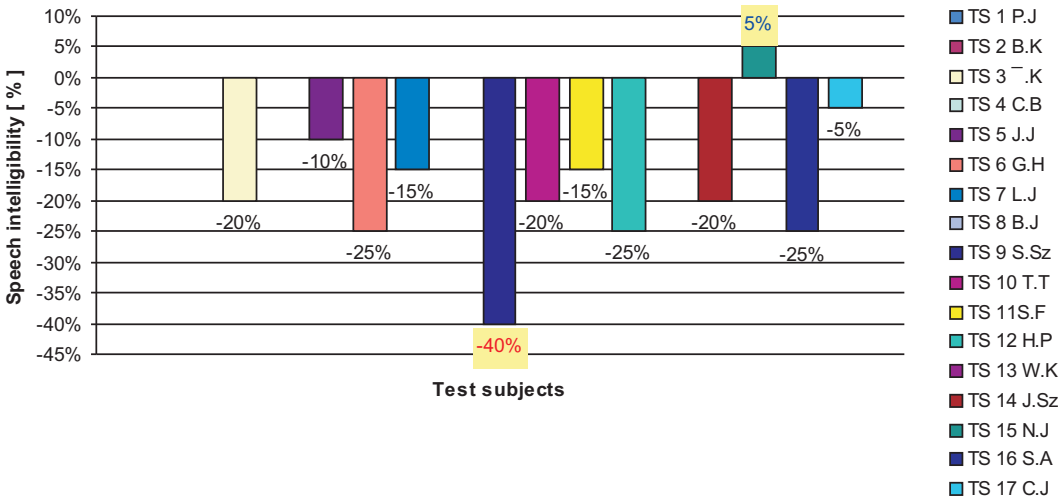


Fig. 8. Scores for monosyllables in the Fastl masking noise for test subjects with hearing aids at adjustable attack (AT) and release (RT) time; Session 5 (see Table 4).

3. Concluding remarks

1. It is commonly known that people with hearing impairments experience a reduction in speech intelligibility in noisy surroundings. The extent of this reduction depends on various characteristics of the patient's hearing. Depending on the degree of the impairment in the temporal resolution of the patient's ear, the ability to perceive words in the time gaps in the masking noise is lost.
2. It has been established that the differences between the speech/noise ratios ΔL for equal speech intelligibility $h = 50\%$ with the fluctuating Fastl noise are surprisingly large for hearing-impaired subjects with or without hearing aids.
3. It is significant that hearing aids can have apparently negative effects on the remaining, almost normal hearing characteristics of hearing-impaired subjects. Presumably the temporal resolution is in particular affected adversely.
4. The extent of the reduction in the temporal resolution of the ear determines whether it is still possible to improve the speech intelligibility by means of a specific selection of the adjustable attack and release times of the hearing aid.
5. It will be necessary to examine to what extent this deterioration in the temporal resolution factor is linked to the comprehension difficulties and what a degree of the speech intelligibility can be achieved by hearing-impaired people, especially when hearing aids with adjustable attack (AT) and release (RT) times in same frequency bands are used.

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