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Research Article

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Speech Perception and Subjective Preference with Fine Structure Coding Strategies

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Abstract

This study aimed to determine differences in speech perception and subjective preference after upgrade from the FSP coding strategy to the FS4 or FS4p coding strategies.

Subjects were tested at the point of upgrade (n=10), and again at 1-(n=10), 3-(n=8), 6-(n=8) and 12 months (n=8) after the upgrade to the FS4 or FS4p coding strategy. In between test intervals patients had to use the FS4 or FS4p strategy in everyday life. Primary outcome measures, chosen to best evaluate individual speech understanding, were the Freiburg Monosyllable Test in quiet, the Oldenburg Sentence Test (OLSA) in noise, and the Hochmair-Schulz-Moser (HSM) Sentence Test in noise. To measure subjective sound quality the Hearing Implant Sound Quality Index was used.

Subjects with the FS4/FS4p strategy performed as well as subjects with the FSP coding strategy in the speech tests. The subjective perception of subjects showed that subjects perceived a ‘moderate’ or ‘poor’ auditory benefit with the FS4/FS4p coding strategy.

Subjects with the FS4 or FS4p coding strategies perform well in everyday situations. Both coding strategies offer another tool to individualize the fitting of audio processors and grant access to satisfying sound quality and speech perception.

Keywords: Cochlear implant; Fine structure; Coding strategy; Signal; Speech perception

Introduction

Coding strategies are used to process sound signals into deliverable electrical stimuli to the auditory system of cochlear implant (CI) users. The sound signals are decomposed into envelope and fine structure [1,2]. The electrical stimuli are delivered to the auditory nerve through an intra-cochlear electrode array. Most modern CI coding strategies present the signal envelope which, depending on the actual implementation of the coding strategy, includes some fine structure information (e.g. information on pitch). With the commonly used Continuous Interleaved Sampling (CIS) strategy the sound signal is split into a number of frequency bands using band-pass filtering, and the envelope is extracted from each frequency band using rectification and low-pass filtering [1,3,4]. These envelope signals are then used to generate amplitude-modulated biphasic pulses at a constant stimulation rate. Each amplitude-modulated pulse train passes into the cochlea through a contact on the multi-electrode intra-cochlear array to stimulate auditory nerve fibers in a specified region of the cochlea. Cochlear tonotopicity is implemented by sending information from the lowest frequency band envelope to the most apical electrode and information from the highest frequency band envelope to the most basal electrode.

Various forms of the CIS strategy are implemented in all major CI systems (Advanced Bionics Corporation: HiRes, Cochlear Corporation: CIS, MED-EL: CIS, CIS+, HDCIS). In addition to the CIS+ and HDCIS strategy, the MED-EL MAESTRO system currently offers the option to configure low-frequency channels up to 300 Hz by using Channel-Specific Sampling Sequences (CSSS) as described by Zierhofer [5]. Such a strategy with CSSS on low-frequency channels is called the FSP strategy. The FS4 and FS4p strategy are further developments of the FSP strategy and were developed in order to give all users access to refined envelope modulations up to 750-1000 Hz. The fundamental principle as well as the manner of providing refined envelope modulations remains the same in FS4 and FS4p as in FSP. FS4 and FS4p use the same CSSS concept and implementation and the same CSSS-specific default parameter settings as FSP.

Recent publications, comparing FSP to older CIS+ coding strategies, reveal that the FSP coding strategy improves speech perception in noise [6-9]. Thus, a further increase in stimulus variability with FS4 and FS4p might benefit individual speech perception and sound quality even further. The main purpose of this study was to determine the effect of upgrade on the speech perception and subjective perception of sound quality of CI users upgraded from the FSP coding strategy to the FS4 or FS4p coding strategy. Primary outcome measures, chosen to evaluate individual speech understanding, were the Freiburg Monosyllable Test in quiet, the Oldenburg Sentence Test (OLSA) in noise, and the Hochmair-Schulz-Moser (HSM) Sentence Test in noise. Subjective sound quality was determined using the Hearing Implant Sound Quality Index ($HISQUI_{19}$). The Hearing Implant Sound Quality Preference Index was used to determine the subjective differences in sound quality between the two different coding strategies.

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Methods

Subjects

10 adult subjects (9 female, 1 male) with a MED-EL CI were included in this study. Demographic data are presented in Table 1. All subjects had more than 10 active electrodes and used their CI more than 10 h per day.

Speech tests

The test set-up consisted of a computer with an onboard sound card, an audiometer, and an audiometric loudspeaker (calibrated according to DIN 45620 and DIN 45624). All speech tests were performed in a sound-proof room. Software for testing was installed on a PC or laptop. The stimuli were generated by the computer and presented to the subject via loudspeaker. The subject was positioned at a fixed distance of 1 m and 0° from the loudspeaker unable to see any information on the computer screen.

The Freiburg Monosyllable Test in quiet, which consists of 20 lists with 20 words each, was presented at 65 dB sound pressure level (SPL). Each subject was tested with one list (List 1) for training purposes before the start of the actual testing. The results scored in this training session were not analyzed. For the actual test each subject was given 2 lists. These lists were allocated according to a randomization procedure. The outcome was calculated as the number of words repeated in % correct.

Oldenburg Sentence Test (OLSA) in noise was performed with a fixed signal (speech) level and a variable noise level. This test established the speech reception threshold (SRT) in noise. The SRT is defined as 50% speech reception in noise and calculated by counting the number of words understood correctly.

The OLSA, which consists of 40 lists with 30 sentences each was tested first with two lists (List 1 and 2) for training purposes. The training run was conducted as a closed-set test. Subjects were given a print-out of all the possible words used in the test. The results scored in this training session were not analyzed. After the training test was run subjects returned the printed word material. For the actual test each subject was given 2 lists according to a fixed randomization procedure. The actual test was performed as an open-set procedure (no word-material was provided as a print out for the test). The subjects had to repeat the words they understood back to the tester who marked them on the standard OLSA case report form. The outcome evaluates the speech perception in noise at a fixed presentation level (speech was presented at 65 dB SPL. The noise used for this test was the OLSA noise. The test was performed at a starting signal-to-noise ratio of +10 dB.

Hochmair-Schulz-Moser (HSM) Sentence Test in noise is an open-set sentence test, which consists of 30 lists with 20 sentences each. Each subject performed one list (List 1) for training purposes before the start of the actual testing. The results scored in this training session were not analyzed. For the actual test each subject was given 2 lists. These lists were allocated according to a randomization procedure. The outcome evaluates the number of correctly repeated words in % correct at a fixed presentation level. Speech was presented at 65 dB SPL. The test was performed in continuous noise at a signal-to-noise ratio of +10dB.

Audio-processor set-up

The patients' usual fitting with the FSP strategy at the time of the first testing interval was used for initial testing with FSP. After the initial testing with FSP, it was saved on the fitting computer and the FS4 or the FS4p coding strategy was fitted to each subject's individual auditory requirements and also stored on the fitting computer. Following this, only FS4 or FS4p programs were programmed to the audio processor. To ensure reproducibility of the collected data subjects were not able to switch back to the FSP strategy during the study period. Therefore, no FSP program options were uploaded on the audio processor. With the OPUS 1 the FS4 or FS4p strategy was stored in all 3 program options with 9 different volume settings.

The following steps were completed during programming of the FS4 or FS4p strategy:

- For all electrodes the maximum comfortable loudness (MCL level) was measured;
- For all electrodes the threshold level (THR) was measured as standard in clinical practice;
- MCLs and THRs were adjusted in combination with the overall volume (given in percentage of MCL) globally until the speech of the investigator was perceived as comfortably loud;
- MCLs and THRs were adjusted until the sound quality was satisfying (test the loudness with spoken voice e.g. 's', 'sh', 'f', 'bub' and environmental sounds e.g. rattling a key, scrunching paper, etc.);
- Optional: The overall volume was adjusted using recorded speech in quiet using an OLSA sentence test at 65 dB SPL.
- The investigator informed the subject about the process in the case of necessary reprogramming of the strategy or any other complications with the study equipment.

Subjective Assessment

The Hearing Implant Sound Quality Index (HISQUI[19]) is a questionnaire used in this study to gain overall information about the

Subject	Gender	Age at time of assessment (years)	Implant Type	Type of Speech Processor	Age at implantation Right Ear (years)	Age at implantation Left Ear (years)	Coding Strategy
1	Female	60.6	PULSAR	OPUS 2	55.7		FS4p
2	Female	67.4	SONATA	OPUS 2		65.0	FS4p
3	Female	72.6	PULSAR	OPUS 2	65.9		FS4p
4	Female	53.4	PULSAR	OPUS 2	47.4		FS4p
5	Female	68.4	PULSAR	OPUS 2		64.6	FS4p
6	Female	54	PULSAR	OPUS 2	49.9		FS4p
7	Female	80.9	SONATA	OPUS 2		78.7	FS4
8	Female	40.9	SONATA	OPUS 2	38.2		FS4
9	Female	56.6	CONCERTO	OPUS 2		55.3	FS4
10	Male	65.8	SONATA	OPUS 2	63.7		FS4

Table 1: Demographic data.

sound quality in personal, everyday listening situations of a hearing implant user. It consists of 19 items on a seven-point Likert scale, with possible answers ranging from ´Always` (7) to ´Never` (1) [10]. A total score is obtained by adding the numerical values of all 19 questions, ranging between 19 and 133 points. A score <30 indicates 'very poor sound quality', a score between 30 and 60 indicates ´poor sound quality´, a score between 60 and 90 indicates 'moderate sound quality', a score between 90 and 110 indicates 'good sound quality' and a score between 110 and 133 indicates 'very good sound quality'.

The investigator explained the procedure for filling out the HISQUI questionnaires to the subject. The questionnaires were filled out at each test interval directly after speech testing at the study site.

Test intervals

The study was of an ABAB design. Every uneven patient number was first tested with the familiar FSP fitting strategy, whereas every even patient number was initially tested with the new fitting strategy (FS4 or FS4p).

Test Interval 1: At switch-over

Speech testing with the FSP or FS4/FS4p (if necessary fit FS4/FS4p before), switch over to other speech coding strategy and do speech testing with this second speech coding strategy, subject to fill out the Hearing Implant Sound Quality Index ($HISQUI_{19}$); send subject home with FS4/FS4p only.

Test Interval 2: One month after switch-over

Speech testing with FSP or FS4/FS4p (use "old" FSP program), switch over to other speech coding strategy and do speech testing with this second coding strategy; subject to fill out the Hearing Implant Sound Quality Index ($HISQUI_{19}$); send subject home with FS4/FS4p only.

Test Interval 3: Three months after switch-over

speech testing with FSP or FS4/FS4p (use "old" FSP program), switch over to other speech coding strategy and do speech testing with the second speech coding strategy; subject to fill out the Hearing Implant Sound Quality Index ($HISQUI_{19}$); send subject home with FS4/FS4p only.

Test Interval 4: Six months after switch over

speech testing with FSP or FS4/FS4p, (use "old" FSP program), switch over to other speech coding strategy and do speech testing with the second speech coding strategy; send subject home with FS4/FS4p only.

Test Interval 5: Twelve months after switch over

speech testing with FSP or FS4/FS4p (use "old" FSP program), switch over to other speech coding strategy and do speech testing with the second speech coding strategy; subject to fill out the Hearing Implant Sound Quality Index ($HISQUI_{19}$); send subject home with FS4/FS4p only.

Statistical Analysis

Group outcome variables were tested for Gaussian distribution and are described by mean values plus standard deviation. In a first step speech performance (Monosyllables in quiet, OLSA in noise and HSM in noise) over time (Interval 1–5) was examined for each coding strategy (FSP and FS4/FS4p), applying repeated measure ANOVAs. Wilcoxon signed-rank test was used to test for a significant difference between the two coding strategies at each tested interval. Additionally, multivariate ANOVAs were conducted to look for a statistically significant effect of coding strategy. Wilcoxon signed-rank test was performed for the $HISQUI_{19}$ to test for a significant difference between the tested intervals.

All p-values are results of two-sided tests, and generally p-values ≤ 0.05 were considered to indicate statistical significance. In cases of multiple comparisons, a p-value of ≤ 0.01 was considered statistically significant. For multiple pairwise comparisons such as analyses between the two coding strategies on speech performance, p-values were adjusted with the Bonferroni correction method. In this case, a p-value ≤ 0.01 indicates statistical significance.

The software tool IBM SPSS Statistics 22 (IBM, Armonik, New York) was used for the statistical analyses.

Results

Speech tests

Freiburg monosyllables in quiet: Over time (Interval 1-5) there were no significant differences in the mean percentage on the Freiburg monosyllables in quiet with the FSP coding strategy ($F(4; 24)=1.989$; $p=0.128$) or with the FS4/FS4p coding strategy ($F(4; 24)=1.343$; $p=0.283$) (Figure 1 and Table 2a).

Overall (across all tested intervals) subjects did not perform significantly better on the Monosyllables in quiet with the FS4/FS4p coding strategy than with the FSP coding strategy (Table 2b).

Oldenburg sentence test (OLSA) in noise: Over time (Interval 1-5) there were no significant differences in the mean score on the OLSA in noise with the FSP coding strategy ($F(4; 24)=1.659$; $p=0.192$) or with the FS4/FS4p coding strategy (Figure 2). However, over time there was a tendency towards an improvement on the OLSA in noise with the FSP/FS4p coding strategy ($F(4; 24)=2.667$; $p=0.057$) (Figure 2 and Table 3a).

Overall (across all tested intervals) subjects did not perform significantly better on the OLSA in noise with the FS4/FS4p coding strategy than with the FSP coding strategy. There was a tendency towards an improvement on the OLSA in noise with the FSP/FS4p coding strategy at test Interval 2 ($p=0.066$) (Table 3b).

Hochmair-Schulz-Moser (HSM) sentence test in noise: Over

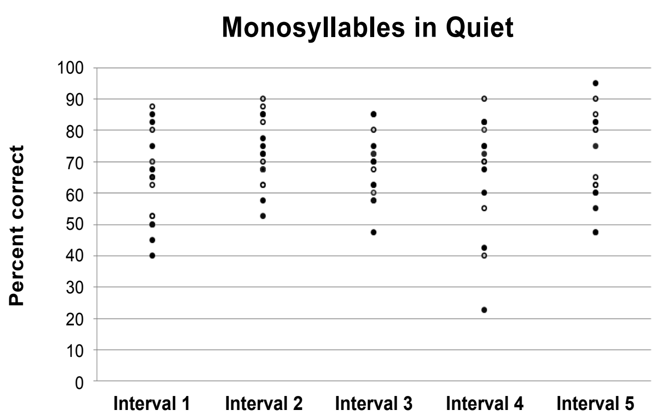

Figure 1: Individual results of monosyllables in quiet (%). Black dots represent results of the FSP coding strategy; black circles represent results of the FS4/FS4p coding strategy.

	Interval 1		Interval 2		Interval 3		Interval 4		Interval 5			
ID	FSP	FS4/FS4p	FSP	FS4/FS4p	FSP	FS4/FS4p	FSP	FS4/FS4p	FSP	FS4/FS4p	Mean FSP	Mean FS4/ FS4p
1	65	65	75	82,5	72,5	80	75	90	60	62,5	69,5	76,0
2	75	70	77,5	85					95	90	82,5	81,7
3	67,5	52,5	72,5	72,5			67,5	70			69,2	65,0
4	82,5	80	85	87,5	85	85	82,5	82,5	82,5	85	83,5	84,0
5	45	50	72,5	67,5	62,5	67,5	60	70	60	62,5	60,0	63,5
6	65	70	67,5	67,5	72,5	60	72,5	80	75	80	70,5	71,5
7	50	50	52,5	62,5	57,5	57,5	22,5	40	55	47,5	47,5	51,5
8	40	52,5	57,5	62,5	47,5	62,5	42,5	55	47,5	65	47,0	59,5
9	85	87,5	85	90	75	70	75	82,5	82,5	80	80,5	82,0
10	67,5	62,5	67,5	70	70	70					68,3	67,5

Bold font shows better value

Table 2A: Individual results on Freiburger Monosyllables in Quiet plus mean over all test intervals.

	FSP	FS4/FS4p	p-value*
Interval 1 (n=10)	64.2 ± 15.14	64.0 ± 13.08	0.943
Interval 2 (n=10)	71.2 ± 10.55	74.7 ± 10.50	.048**
Interval 3 (n=8)	67.8 ± 11.60	69.1 ± 9.53	0.588
Interval 4 (n=8)	62.2 ± 20.15	71.2 ± 16.58	.018**
Interval 5 (n=8)	69.7 ± 16.44	71.6 ± 14.39	0.67

*Results of Wilcoxon signed-rank test
**Because of multiple comparisons, a p-value ≤ 0.01 indicates statistical significance

Table 2B: Freiburger monosyllables in quiet as mean percent ± standard deviation.

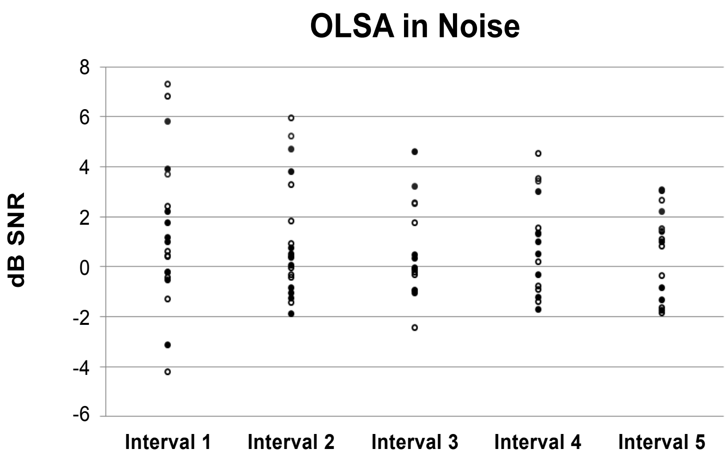

Figure 2: Individual results of OLSA in noise (dB SNR). Black dots represent results of the FSP coding strategy; black circles represent results of the FS4/FS4p coding strategy.

time (Interval 1-5) there were no significant differences in the mean percentage on the HSM in noise with the FSP coding strategy (F(4; 24)=0.234; p=0.917) or with the FS4/FS4p coding strategy F(4; 24)=0.660; p=0.626) (Figure 3 and Table 4a).

Overall (across all tested intervals) subjects there were no significant differences between the mean percentage with the FS4/FS4p coding strategy and the mean percentage with FSP coding strategy on the HSM in noise (Table 4b).

Subjective assessment

Hearing implant sound quality index ($HISQUI_{19}$): The mean average score on the $HISQUI_{19}$ was 78.5 (± SD=21.9) at Interval 1, 41.7 (± SD=24.4) at Interval 2, 47.7 (± SD=30.3) at Interval 3 and 77.9 (± SD=20.2) at Interval 5. Subjects reported ´moderate` self-perceived sound quality at Interval 1 and 5 and ‘poor’ self-perceived sound quality at Interval 2 and at Interval 3. The results show a significant deterioration at Interval 2 and 3 compared to Interval 1 (p=0.005 and

	Interval 1		Interval 2		Interval 3		Interval 4		Interval 5			
ID	FSP	FS4/FS4p	FSP	FS4/FS4p	FSP	FS4/FS4p	FSP	FS4/FS4p	FSP	FS4/FS4p	Mean FSP	Mean FS4/ FS4p
1	1,745	0,6	0,365	-0,05	-0,135	-0,23	-1,725	-0,785	3,045	1,515	0,659	0,21
2	-0,215	0,425	-1,91	-0,33					-1,765	-1,865	-1,297	-0,59
3	1,155	6,8	-0,86	3,29			-0,33	4,52			-0,012	4,87
4	-0,235	-0,445	-1,285	0,405	-0,95	-0,33	-1,25	-0,92	-1,35	-0,375	-1,014	-0,333
5	0,995	2,395	0,49	1,8	-0,105	1,745	0,5	0,19	1,385	1,085	0,653	1,443
6	5,8	3,7	4,7	5,2	3,2	2,5	1,3	3,4	2,2	1,5	3,44	3,26
7	3,9	7,3	3,8	5,95	4,6	2,55	3	3,5	3,05	2,65	3,67	4,39
8	-0,55	-1,3	-1,05	-1,45	-1,05	-2,45	1	-1,4	-0,85	-1,65	-0,5	-1,65
9	2,21	0,395	0,75	0,925	0,32	-0,075	1,345	1,525	1	0,8	1,125	0,714
10	-3,14	-4,21	0,05	-0,45	0,475	-0,975					-0,872	-1,878

Bold font shows better value

Table 3A: Individual results on OLSA in noise plus mean over all test intervals.

	FSP	FS4/FS4p	p-value*
Interval 1 (n=10)	1.17 ± 2.49	1.57 ± 3.57	0.959
Interval 2 (n=10)	0.50 ± 2.16	1.53 ± 2.51	0.066
Interval 3 (n=8)	0.79 ± 2.02	0.34 ± 1.77	0.263
Interval 4 (n=8)	0.48 ± 1.54	1.25 ± 2.31	0.208
Interval 5 (n=8)	0.84 ± 1.94	0.46 ± 1.61	0.123

*Results of Wilcoxon signed-rank test

Table 3B: OLSA in noise as dB SNR ± standard deviation.

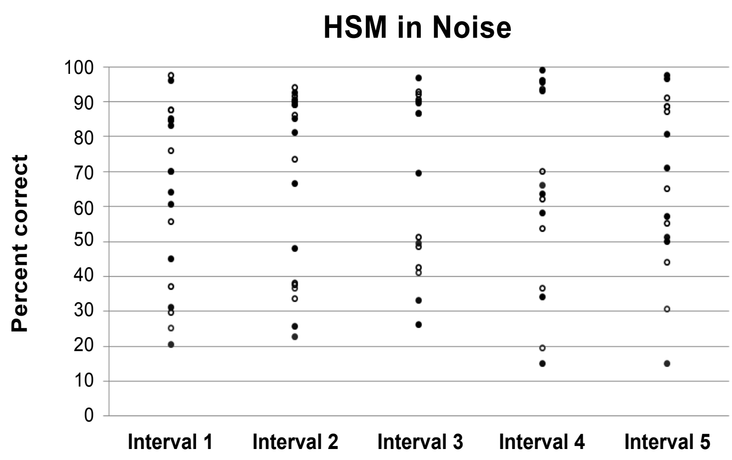

Figure 3: Individual results of HSM in noise (%). Black dots represent results of the FSP coding strategy; black circles represent results of the FS4/FS4p coding strategy.

p=0.012), but in turn a significant improvement from Interval 2 and 3 to Interval 5 (p=0.018 and p=0.028).

Discussion

This study compared subjects with the FSP coding strategy after upgrade to the FS4 and the FS4p (FS4/FS4p) coding strategies, over 12 months. Subjects with the FS4/FS4p strategy performed as well as subjects with the FSP coding strategy. The primary outcomes measures: the Freiburg monosyllables in quiet, OLSA and HSM test, determined that the performance with both coding strategies were similar. The subjective assessment of subjects showed that half of the time they perceived a moderate improvement in auditory benefit or a poorer sound quality with the FS4/FS4p than with the FSP coding strategy.

The subjects tested herein did not perform significantly differently on the Freiburg monosyllables in quiet test with the FS4/FS4p coding strategy than with the FSP coding strategy. In contrast, Riss et al. [11] had shown that subjects tested on the Freiburg monosyllables in quiet with FS4 had a small, but significant difference in favour of the FSP strategy. A possible explanation for the difference between the Riss et

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	Interval 1		Interval 2		Interval 3		Interval 4		Interval 5			
ID	FSP	FS4/FS4p	FSP	FS4/FS4p	FSP	FS4/FS4p	FSP	FS4/FS4p	FSP	FS4/FS4p	Mean FSP	Mean FS4/ FS4p
1	85	87,5	85	86	90	92	99	96	71	65	86	85,3
2	64	76	92,5	91,5					97,5	88,5	84,7	85,3
3	70	70	90	90			63,5	70			74,5	76,7
4	83	87,5	89	94	86,5	90,5	93	93,5	96,5	91	89,6	91,3
5	45	37	66,5	38	69,5	51	58	53,5	57	55	59,2	46,9
6	20,5	25	22,5	36,5	49,5	41	66	19,5	15	30,5	34,7	30,5
7	31	29,5	25,5	33,5	33	48,5	15	36,5	51	44	31,1	38,4
8	60,5	55,5	48	37,5	26	42,5	34	62	50	87	43,7	56,9
9	96	97,5	90,5	89	86,5	92,75	96	95,5	80,5	88,5	89,9	92,7
10	84,5	84,5	81	73,5	96,7	89,62					87,4	82,5

Bold font shows better value

Table 4A: Individual results on HSM in Noise plus mean over all test intervals.

	FSP	FS4/FS4p	p-value*
Interval 1 (n=10)	63.9 ± 25.02	65.0 ± 26.51	0.623
Interval 2 (n=10)	69.0 ± 27.40	66.9 ± 26.89	0.722
Interval 3 (n=8)	67.2 ± 27.57	68.5 ± 24.52	0.889
Interval 4 (n=8)	65.6 ± 30.26	65.8 ± 28.65	0.833
Interval 5 (n=8)	64.8 ± 27.54	68.7 ± 23.56	0.779

*Results of Wilcoxon signed-rank test

Table 4B: HSM in Noise as mean percent ± standard deviation.

al. study and the present data may be the difference in follow-up period [11]. The Riss et al. study followed-up patients over 4 months; whereas the present study looked at the patients over 12 months [11]. Punte et al. and Vermiere [6,12] have both shown that subjects tend to need some experience (12-24 months) before fine structure becomes useful to them [6-9]. The subjects included herein had at least 12 months, of more than 10 h per day FSP use, before upgrade to the FS4/FS4p coding strategy. However, upon upgrade the subjects may have needed even more time to appreciate the differences or were already well adjusted to fine structure conditions in quiet.

Comparing FSP to older CIS+ coding strategies has shown that the provision of fine structure via an audio processor improves speech perception in noise [13-16]. As the subjects in the present study are already so used to their CI with fine structure coding from the FSP strategy, it could be that the differences were not obvious. Similarly, some published literature indicates that with other approaches to better code the temporal structure, by enhancing the channel envelope modulations, changes in speech perception scores are relatively small (as mainly areas of low frequencies are stimulated) [13-16]. Thus, on the speech tests subjects did not perform significantly better than with the FSP coding strategy. Nonetheless, the hearing performance of the subjects was no worse with the new FS4/FS4p coding strategy than with FSP.

However, the outcomes of the $HISQUI_{19}$ showed that at 2 out of 4 intervals (Interval 1 and 5) subjects perceived the level of auditory benefit as 'moderate'. It is difficult to compare different subjective measures between studies. The $HISQUI_{19}$ is a newly validated and reliable questionnaire designed to be used across all studies to determine the subjectively perceived sound quality of hearing implant users [10]. Introduced in 2014, there are to date few studies available with the $HISQUI_{19}$. However, the aforementioned studies, by Punte et al. and Vermeire et al., performed over a longer follow-up period, used the Speech; Spatial and Qualities of Hearing Scale (SSQ) to determine subjective perception [6,12]. $HISQUI_{19}$ outcomes correlate strongly with the SSQ [17]. Comparing, FSP to traditional CIS+ coding strategies showed that subjects benefitted significantly from the provision of fine structure on the SSQ questionnaire in both studies. In the Riss et al. study, one of the few studies to compare FSP and FS4/FS4p very little difference in the subjective perception of sound quality between coding strategies was described [12]. With two subjects detecting 'very little difference' in sound quality between the FSP and FS4 coding strategies, and another two subjects stating that they experienced 'less recognized differences'. Similarly, in the present study, at Interval 2 and 3, the perception of auditory benefit was perceived as 'poor'. Although, we suspect that because subjects were already used to the fine structure coding from the FSP strategy the perceived differences were less obvious but subjects generally appreciated the new coding strategy.

To establish a complete picture of the rehabilitation of CI users, quantification of sound quality is of increasing importance [17,18]. Therefore, given the preference of some individuals to particular coding strategies and that satisfaction cannot be predicted from speech testing; the subjective preference of a certain speech coding strategy should be recognized as an outcome of growing importance. Identification of an individual's subjective preference for a given coding strategy gives audiologists and clinicians greater opportunities to meet the individual needs of the implant recipient.

Conclusion

The FS4/FS4p coding strategy works well in experienced CI recipients and represents a further tool to individualize the fitting of audio processors. This grants access to more satisfying sound quality and speech perception. The subjective perception of individual's experiences indicates that in a real life situation many subjects benefit from the use of the FS4/FS4p coding strategy.

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