

Evaluation of dual and fast-acting AGC systems in cochlear implants: initial results

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Background Both acoustic hearing aids and cochlear implant sound processors apply Automatic Gain Control (AGC) to compress the large dynamic range of everyday sounds into the small dynamic range available to cochlear implant users. However, compared to the work carried out for acoustic hearing aids [Moore and Glasberg, 1988], relatively little work has been done to optimize AGC systems for cochlear implants. We compared two different types of single-channel AGC: a fast-acting syllabic compressor (AGC1) and the dual-time constant system (AGC2) developed by Moore et al (1991) in Cambridge. Figure 1 illustrates the AGC2 concept; the time constants are given in table 1. Two gain control loops are used, one responding quickly to protect the user from sudden intense events, the other acting slowly to maintain essentially a constant volume. The loop with the higher control voltage, usually the slow loop, determines the gain and the fast loop acts only when needed to deal with a sudden increase in sound level. Usually, the gain changes slowly, avoiding distortion of the temporal envelope, and hence maximizing speech intelligibility.

	Attack	Recovery
AGC1	2	240
AGC2 Fast	3	80
AGC2 Slow	240	1500

Table 1: Time constants for fast acting (AGC1) and dual-loop (AGC2) Automatic Gain Control algorithms, times in ms, ANSI (1996)

Method A group of six profoundly deaf adult subjects was studied. The subjects were post-lingually deafened, unilaterally implanted, and used the Advanced Bionics Auria[®] sound processor. All subjects had implant experience of at least three years and hence had stable programs, created using the SoundWave[®] fitting software. Subject demographics are shown in table 2.

Initially, a baseline measurement was made using the "standard" program, which was based on AGC2. Subjects were then fitted using research software which allowed the AGC algorithm to be selected from AGC1 or AGC2. Where possible, all other program parameters remained unaltered. Subjects were randomly allocated to start with either AGC1 or AGC2. After programming, basic comfort was checked and the subject held a conversation for approximately ten to fifteen minutes using the new program. Speech perception with the new program was then assessed (except for subject 1). This is referred to as "acute" measurement. The subject returned one month later for re-assessment after long-term use.

Following assessment of the program used over the past month, the alternative AGC program was fitted. Comfort was again checked, and after a brief acclimatization period speech perception was assessed. The subject returned one month later for re-assessment, and was then re-fitted with their clinical program. In case changes to the program were required, these were then made in the routine clinical manner.

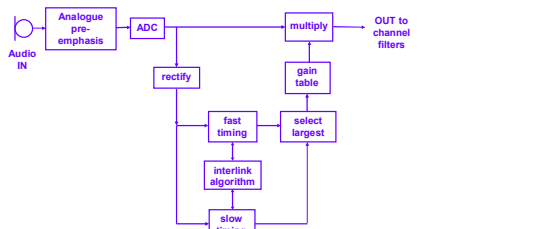


Figure 1: Block diagram of the dual-loop AGC system (AGC2)

Two speech perception tests were used to assess benefit: One measured percent correct for a fixed signal-to-noise ratio (SNR). The other used an adaptive procedure to measure the speech reception threshold (SRT), while the overall level was varied over a 20-dB range. The fixed SNR was selected for each subject in pilot trials to give a score in the range 30% to 70% correct. Once a SNR was assigned, this was used in all subsequent test sessions. The sentences came from the HSM test, which uses speech shaped noise as the background [Hochmair-Desoyer et al., 1997]. A practice list was always given for each speech test before data were collected. Each data point was based on two lists of HSM sentences (40 sentences) for the fixed SNR test, and a total of 30 sentences for the SRT score. Apart from in practice, no test list was repeated during the study.

Subject	Age	Duration of deafness	Age at CI	Implant Experience	Aetiology
1	72	3	69	3	Sudden, unknown
2	74	0	71	3	Unknown
3	71	7	68	3	Unknown
4	68	2	64	4	Menieres
5	37	2	33	4	Rubella
6	55	1	51	4	Unknown

Table 2: Subject demographics. Times are in years. Acute data were available for subjects 2 to 6. Data after long-term experience were available for subjects 1 to 3.

Results Figure 2 shows the individual results which have been collected to date: "*" represent the five acute measurements, while "+" represent the three measurements after long-term experience. All data points appear above the diagonal (blue line) meaning that all subjects scored better with AGC2 than with AGC1. The scores after long-term experience appear closer to the leading diagonal suggesting that learning takes place with long term experience of AGC1. Figure 3a shows the group mean scores for the five acute measurements. Based on a matched-samples two-tailed t-

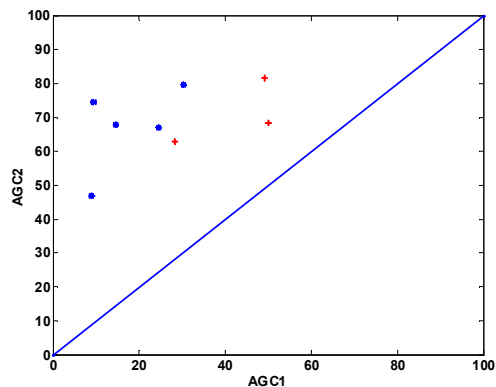


Figure 2: AGC2 scores plotted against AGC1 scores for speech in noise. The SNR for each subject was the same for AGC1 and AGC2

test, the scores with AGC2 (mean 67.2, range 47 to 80) were significantly higher than those for AGC1 (mean 17.5, range 9 to 30), $p < 0.001$. Figure 3b shows the mean SRT scores for the acute measurements. In this case a lower score is associated with better performance. The AGC2 SRT (mean 4.3 dB, range -0.8 to 10.8) was significantly better than the AGC1 SRT (mean 9.9 dB, range 5.8 to 15.3), $p=0.01$. Three subjects had completed both acute and long-term AGC1 test sessions. The mean scores for these were 21.4 and 39.2%, respectively, showing a significant learning effect ($p < 0.005$). For the four subjects who had completed both acute and long-term test sessions for AGC2, the mean scores were 67.3 and 65.5%, respectively, which were not significantly different ($p=0.632$).

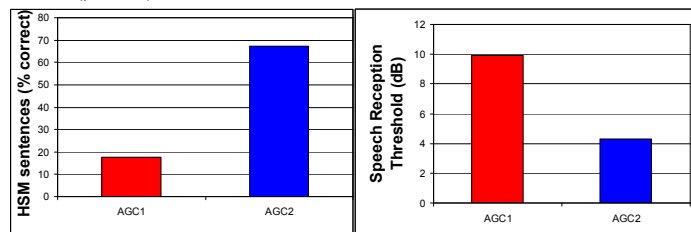


Figure 3: (a, left) mean percent words correct for the acute measurements with AGC1 and AGC2 on the HSM sentences presented in noise; (b, right) mean SRT scores for the same subjects, tested with overall presentation level roved randomly over a 20-dB range

Discussion While significantly better performance was found for AGC2 when tested in noise, all subjects were able to make use of both AGC algorithms. Little difference was reported between AGC types when listening in quiet. Two subjects requested a modest increase in volume when using AGC1. One subject commented that AGC1 might sound a little more "damped" than AGC2. Since the clinical program incorporated AGC2, little learning was expected for the AGC2 research program and indeed none was found. There was a strong learning effect (difference between the acute and long term measurements) with AGC1. Despite subjects performing better on AGC1 following the one month of experience, immediately on changing to AGC2, large improvements were seen. The results from both the fixed SNR test and the roving presentation level SRT test were very consistent for the acute data. All subjects scored better with AGC2 for both tests. The magnitude of the difference between AGC1 and AGC2 scores was surprisingly large. This highlights the need to conduct testing in challenging listening conditions in order to evaluate how implant users are likely to perform in everyday life, the roving of presentation level being particularly relevant.

Conclusions The dual-loop AGC system (AGC2) performed significantly better than the fast-acting syllabic compressor (AGC1) when tested in competing noise. In contrast, subjects reported only minor differences between the two AGC algorithms when listening in quiet. This underpins the need to evaluate algorithms in competing noise. Future work should be aimed at optimizing the dual-loop AGC parameters for cochlear implant users.

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