Effect of envelope low pass filtering on melody recognition

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Introduction

- The recent study by Smith *et al.* (2002) with normal-hearing listeners, showed that the speech fine structure contains important information for pitch perception and spatial localization.
- On a melody recognition task, subjects were able to identify the melodies accurately when the music stimuli were processed through a small number of channels (1-8) and the fine structure was preserved.
- In this study we examined whether cochlear implant listeners are able to identify melodies accurately when a speech coding strategy is used that preserves fine temporal cues.

Introduction (cont-ed)

- For this study, we chose to use Clarion S-Series implant patients fitted with the Simultaneous Analog Stimulation (SAS) speech processing strategy - a strategy known to provide fine time-envelope information.
- The fine time-envelope information was systematically reduced by low-pass filtering the speech-envelope with with cutoff frequencies ranging between 100 and 1200 Hz.
- The hypothesis of the present experiment is that if cochlear implant patients are able to extract fine structure information for melody recognition, then low-pass filtering the speech envelope ought to reduce their performance in melody recognition.

Methods

- **Subjects**
  Six adult Clarion S-Series implant users participated in this study. All subjects were native speakers of American English and had been wearing the Clarion S-Series implant programmed with the SAS strategy for over six months.
- **Melody Material**

  34 common piano melodies with all rhythmic information removed (Hartmann and Johnson, 1991) were used. Melodies consisted of 16 equal-duration notes synthesized with MIDI software using samples of a grand piano. These melodies were also used in the Smith *et al*. (2002) study.

Signal Processing

- The SAS strategy was implemented on the Clarion Research Interface-I platform, which is based on the Motorola DSP56309 processor.
- The signal was first pre-emphasized, and then applied to a bank of ***7*** bandpass filters. The bandpass filter outputs were full-wave rectified and low-pass filtered with cutoff frequencies of 100 Hz, 200 Hz, 400 Hz, 800 Hz and 1200 Hz.
- The low pass filters were second-order elliptical filters. The filters were designed with the MATLAB signal processing toolbox and the filter coefficients were quantized to 24 bits.

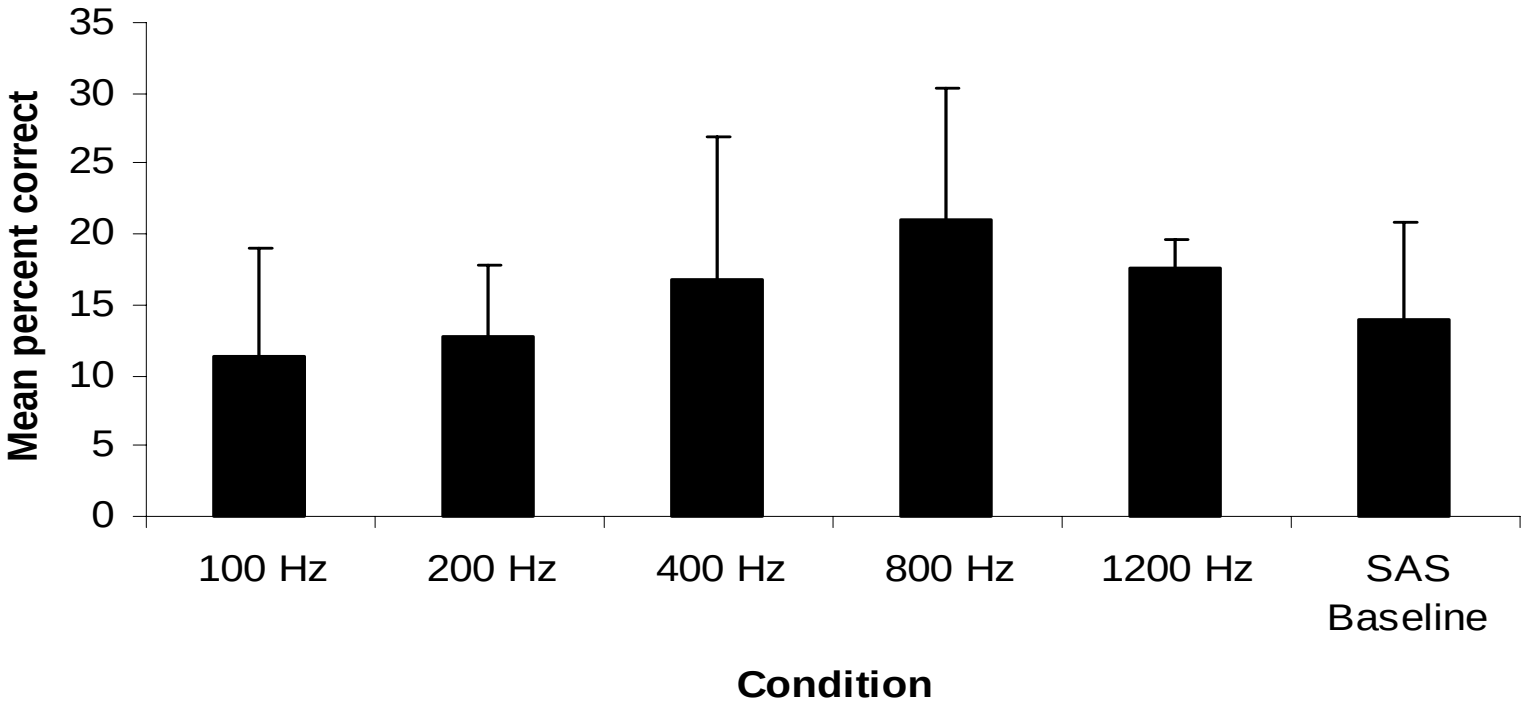
Procedure

- The melodies were processed through envelope filters with cut-off frequencies of 100 Hz, 200 Hz, 400 Hz, 800 Hz and 1200 Hz plus one condition where the original SAS baseline algorithm was used (without envelope filtering).
- For each low pass filter condition, the melodies were all randomized and presented to the subjects for identification. Melodies were presented in two blocks of three repetitions each. All conditions were counterbalanced across subjects to avoid any order effects.
- The melodies were played through a Creative SB Live sound card in the PC to the auxiliary input connector of the speech processor.
- Before testing, the subjects were asked to select 10 melodies from a list of 34 that they were familiar with. The subjects were given a practice session in which the identity of each melody was revealed to them while it was being played. The SAS baseline strategy (with no filtering) was used in the practice session.

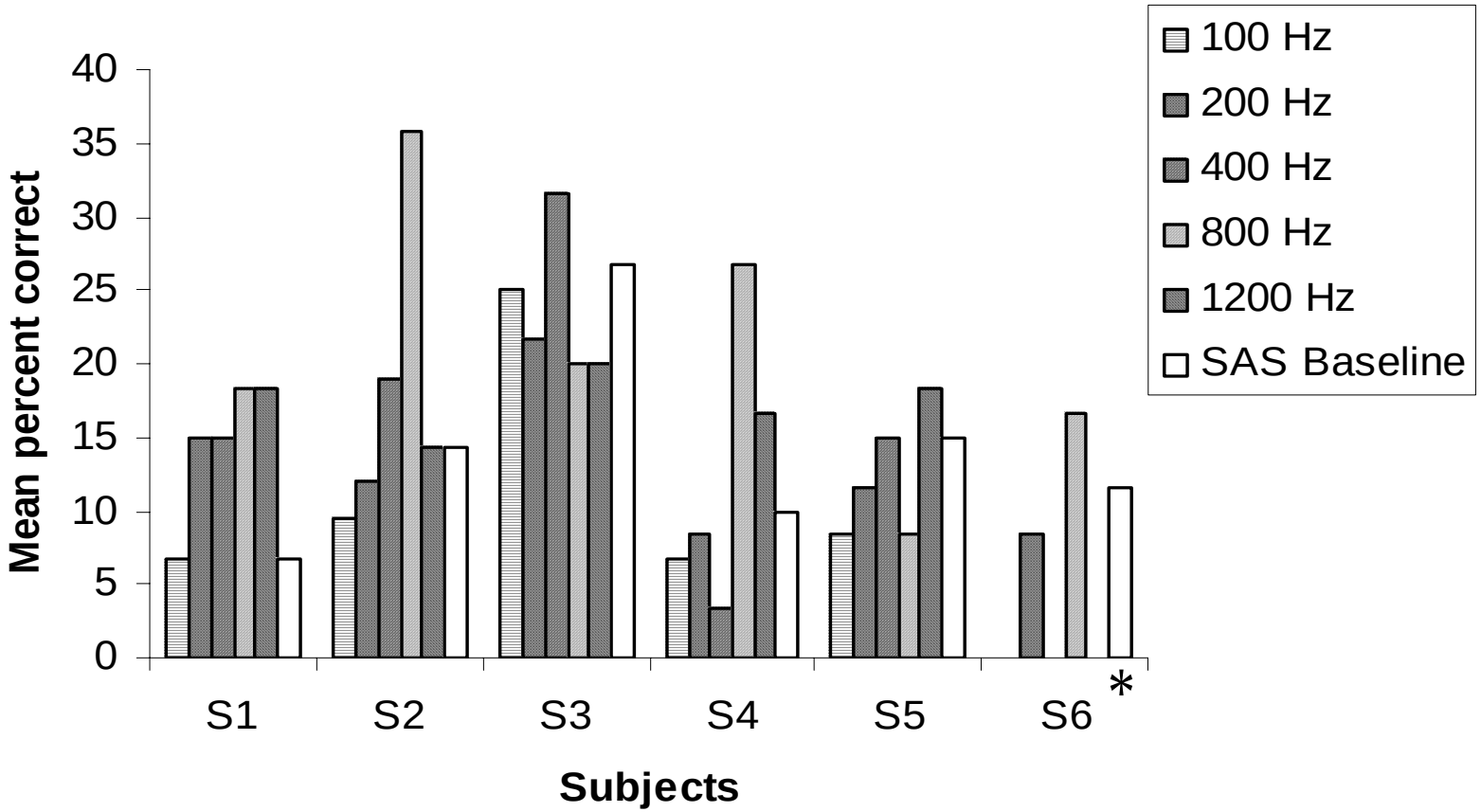
Subject demographics

Subject	Gender	Age (years) at detection of hearing loss	Age fit with Clarion S-series	Etiology of hearing loss
S1	F	Congenital	38	Hereditary
S2	M	Congenital	50	Hereditary
S3	F	16	39	Middle ear infection
S4	F	20	55	Unknown
S5	M	10	53	Unknown
S6	M	30	30	Blunt trauma

Mean results



Individual subject results



*S6 was not tested with the 200 and 800 Hz conditions

Analysis

- A repeated measures ANOVA showed no significant effect [$F(5,20)=1.6$, $p=0.19$] of envelope cutoff frequency.
- Mean results indicated that for most conditions, subjects performed near chance level (10%).
- Individual data showed that some subjects (S2, S4) performed better with the 800-Hz condition.

Discussion and conclusions

- Contrary to the original hypothesis, limiting the amount of fine-temporal information available did not affect cochlear implant listener's performance on melody recognition.
- This suggests that implant listeners are not able to extract or make use of fine structure information available in the speech signal.
- The inability of subjects to use fine structure cues might be due to: (1) the overly synchronized auditory response to electrical stimulation, and (2) the current spread responsible for channel interaction.

Discussion and conclusions

- One approach previously proposed for dealing with the over-synchronized stimulation is to use high-rate conditioner pulses (Rubinstein *et al*., 1999).
- It should be noted that the present study used relatively difficult (for the CI users) music material, namely non-rhythmic melodies. Further studies are needed to investigate the effect of envelope cutoff frequency using melodies that contain rhythmic information.
- Overall, the present findings point to the need of techniques to deliver (perhaps at the auditory nerve level) fine-structure information to implant listeners. Such techniques are needed by implant listeners for better music appreciation.

Acknowledgements

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References

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