

New concepts for signal processing in cochlear implants

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Evolution of CI strategies

- **Deterministic approaches**
 - Nucleus $F_0/F_1/F_2$
 - Speak (Spectral Peak, Skinner et al. 1994; Seligman and McDermott, 1995)
- **Whole signal approach**
 - CIS (Continuous interleaved sampling Wilson, 1991)
- **Redundancy reduction approaches**
 - ACE (Advanced Combination encoder Arndt et al. 1999; Vandali et al. 2000)
 - PACE/MP3000 (MP3)

Driving principle in the past

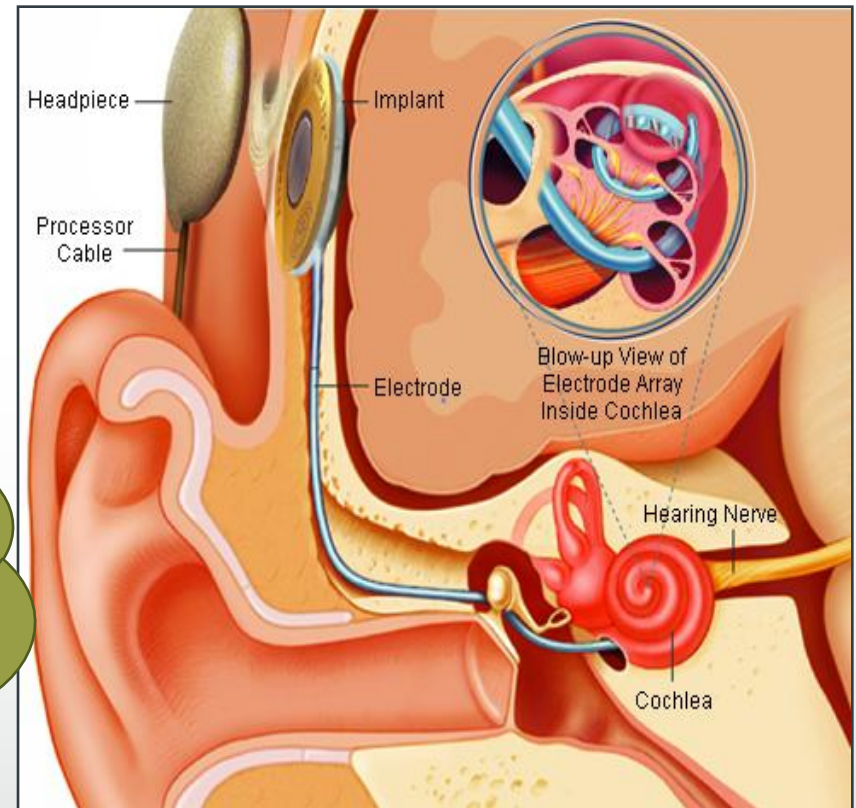


**More is
better!**

Cochlear implants

- Limited frequency resolution
- Limited time resolution
- Limited dynamic range

**Transmission
bottleneck!**



How do we deal with the bottleneck?



**Less is
better!**



**Sparse
coding**

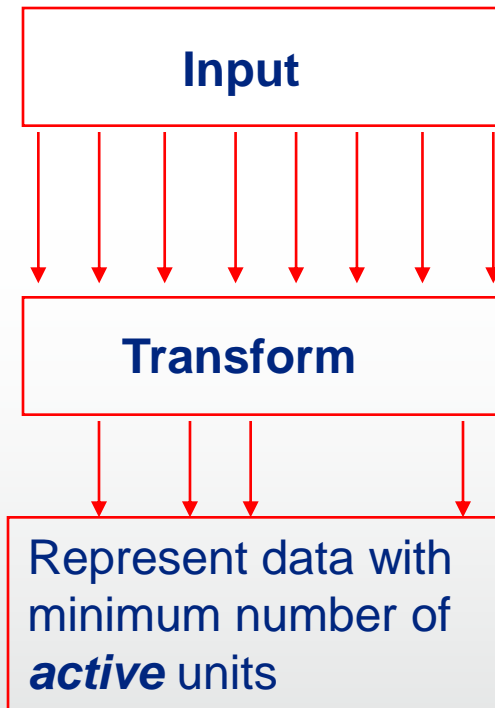
Rationale 1 for sparse coding: information theory

- Where there is an transmission bottleneck, best to transmit only the most important information
- Transmitting less information effectively can be better than trying to transmit too much information and distorting the most important information
- Importance can be defined for signals in either a deterministic or a statistical sense: we use the statistical sense here, in terms of contrasts in the time-frequency domain

Rationale 2 for sparse coding: sensory systems

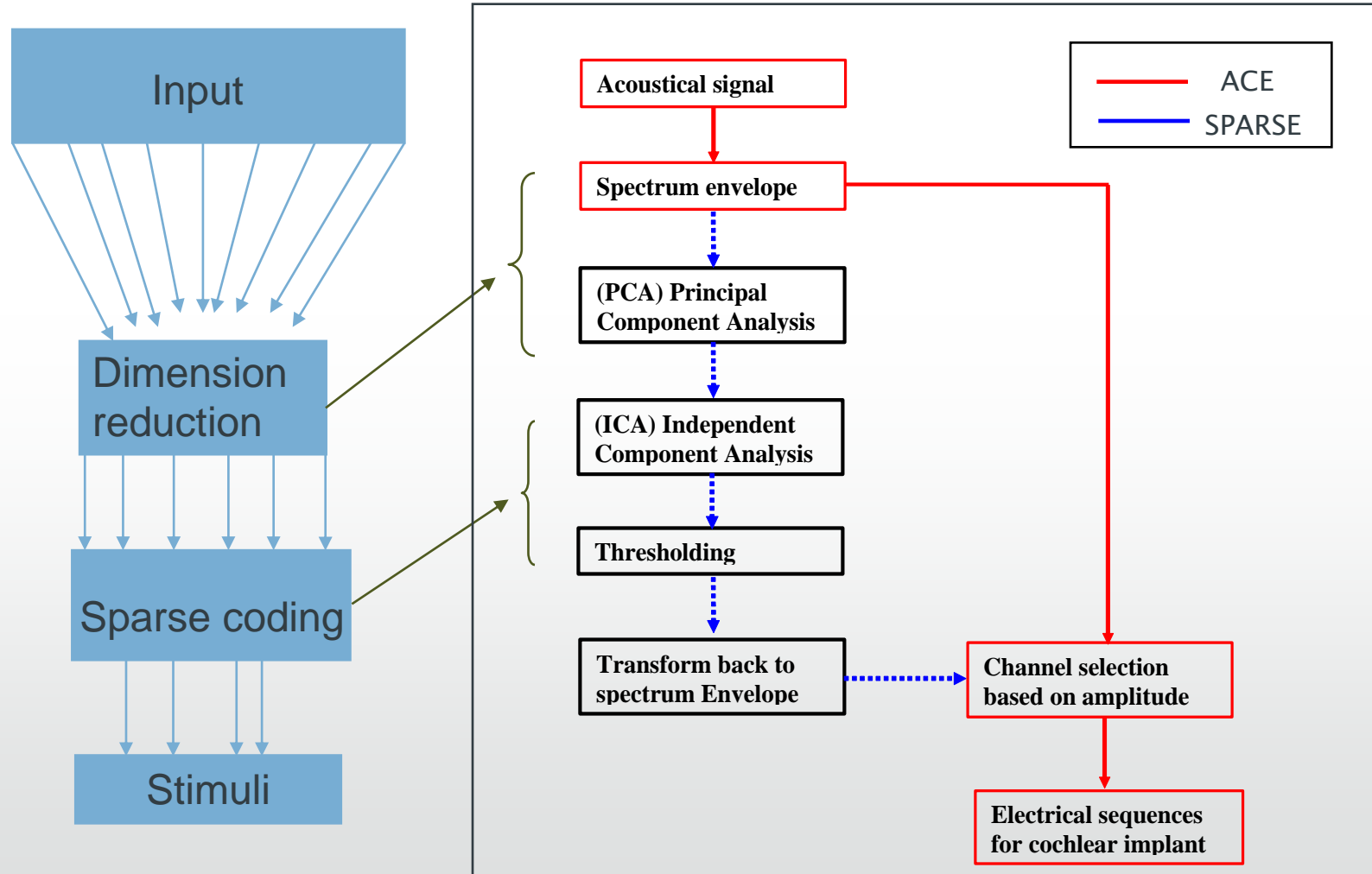
- At any time, only few neurons are simultaneously active.
- Sparse coding probably happens both in the peripheral and cortex level
- Using the limited coding resources efficiently!

illustration of sparse coding



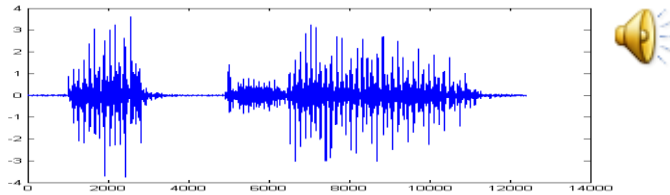
What is the goal of sensory coding?
Field, 1994

SPARSE strategy overview

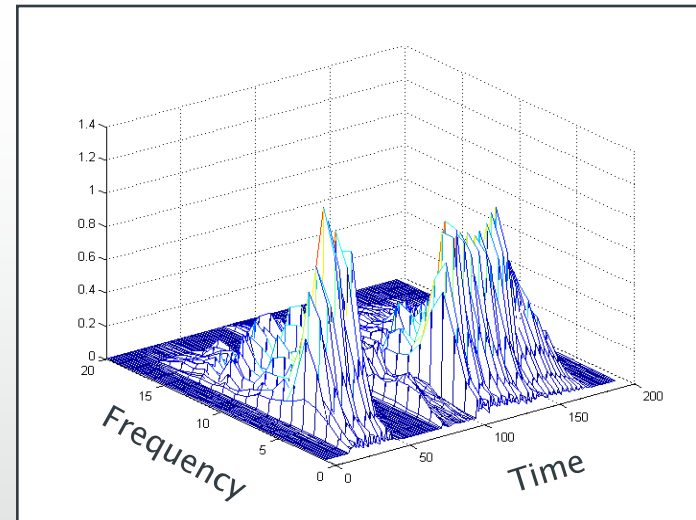
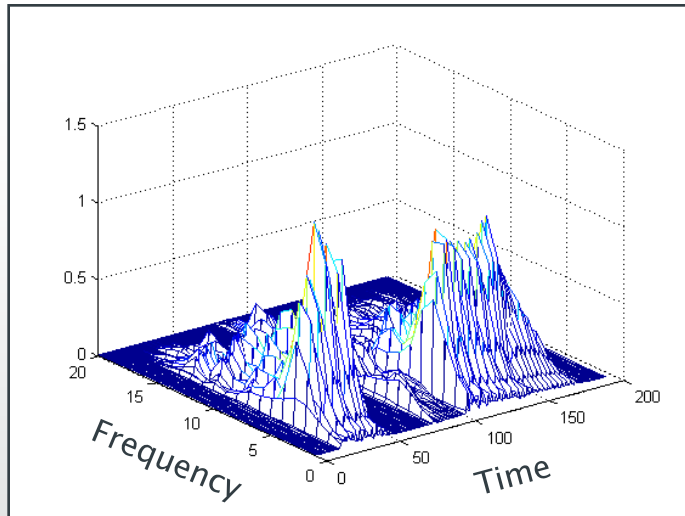
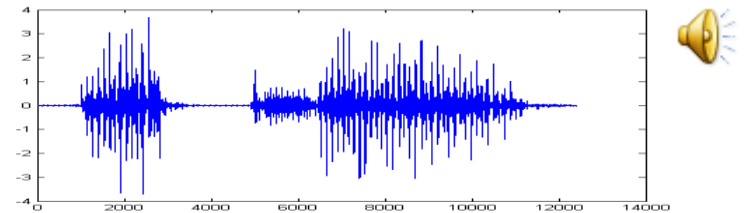


Principal Component Analysis

/aKa/ using ACE



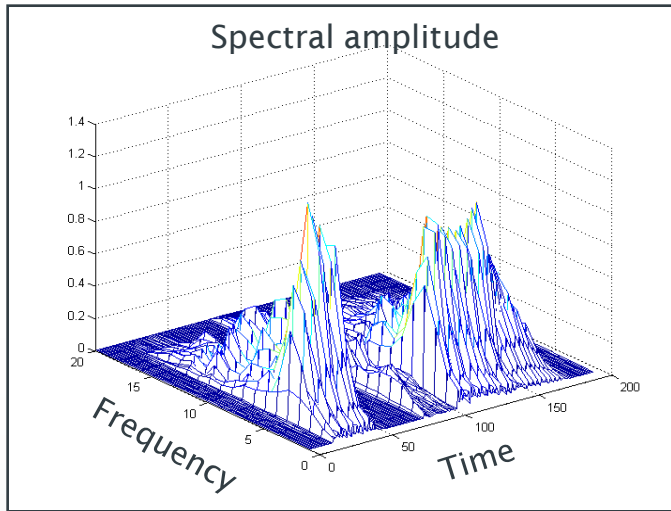
/aKa/ ACE+PCA



ACE (22 channels)

PCA (8 Eigen)

Independent Component Analysis

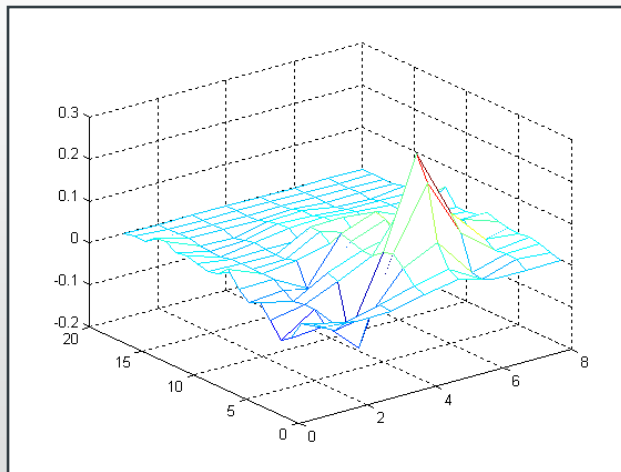


Size=22*194

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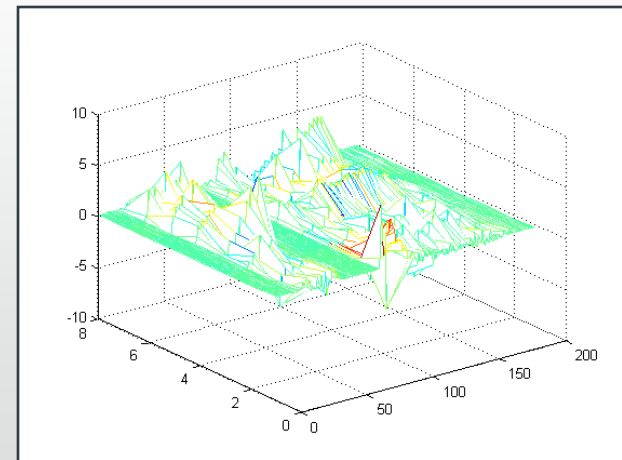
A

Independent components



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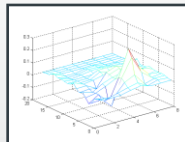
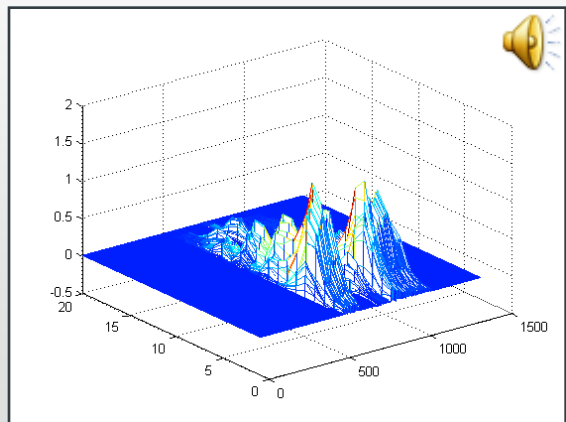
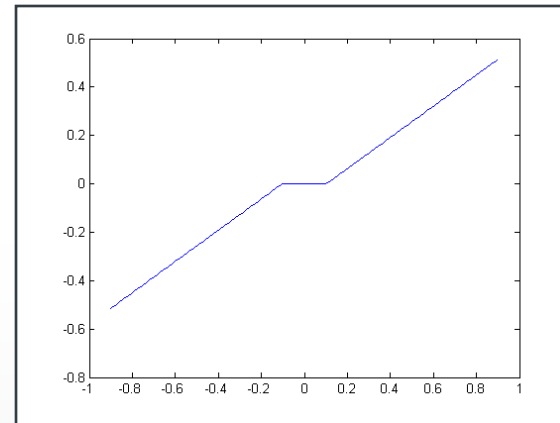
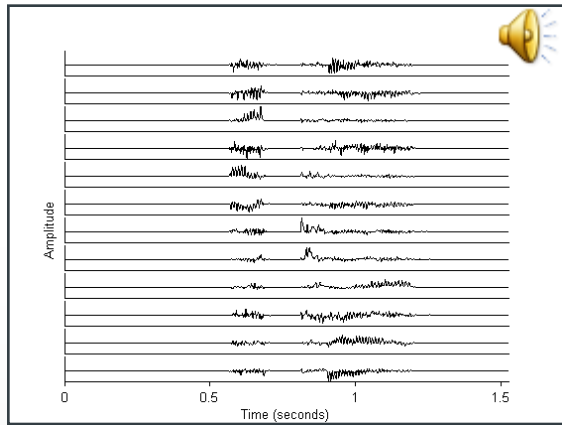


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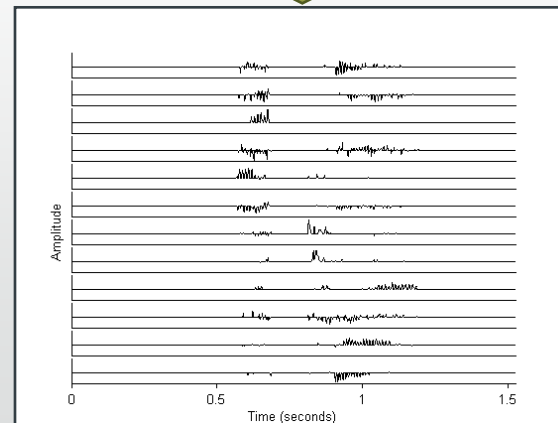
Sparse representation in quiet

Independent components

Thresholding

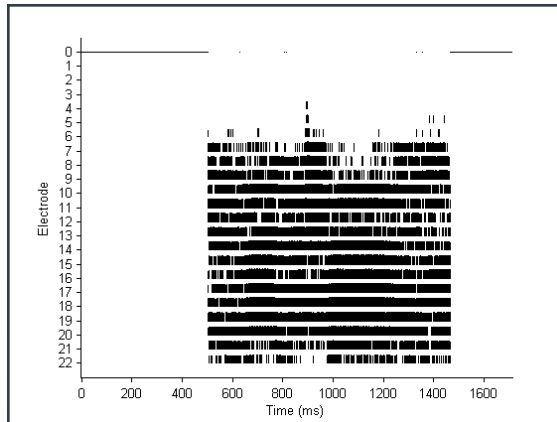


$= A *$

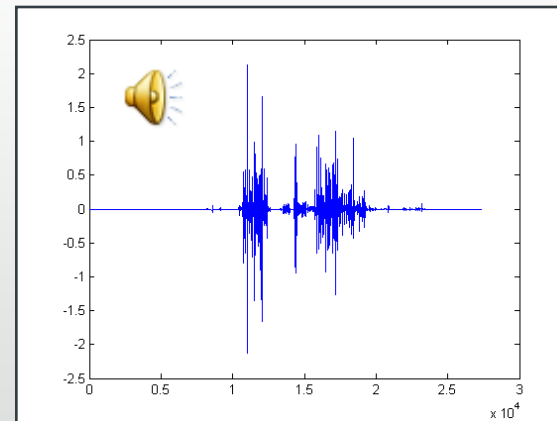
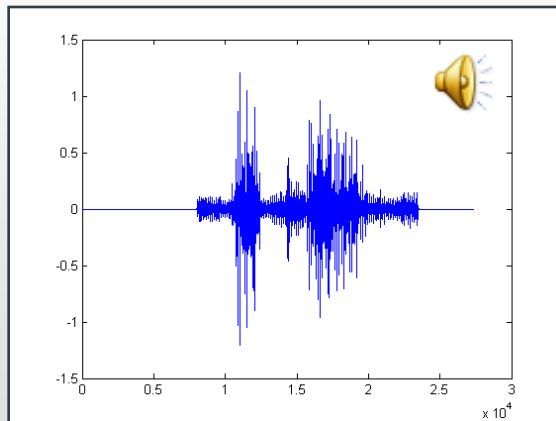
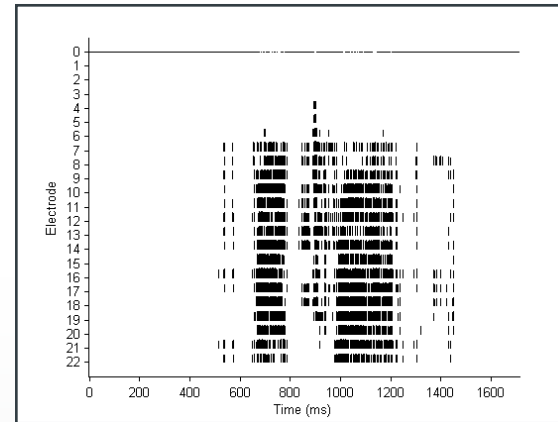


When in noise...

ACE

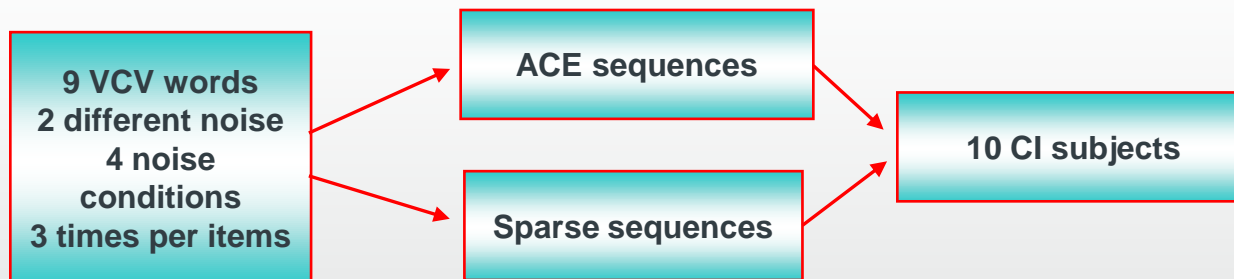


SPARSE



Experiments

- Aim: Compare ACE and new SPARSE strategy
- Methods: NIC streaming to compare subjective performance of CI users
- Materials: VCV words in noise (babble stationary noise and modulated noise)



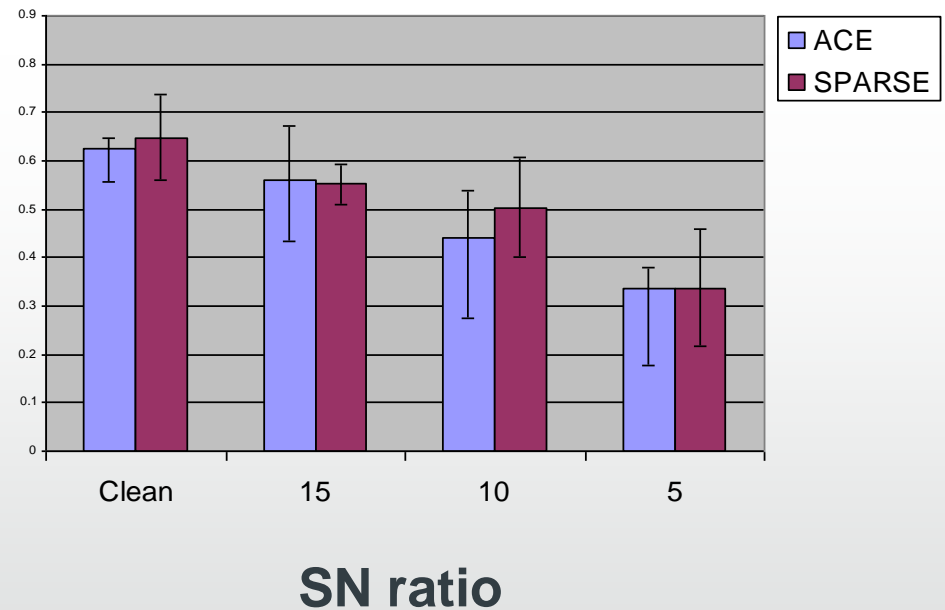
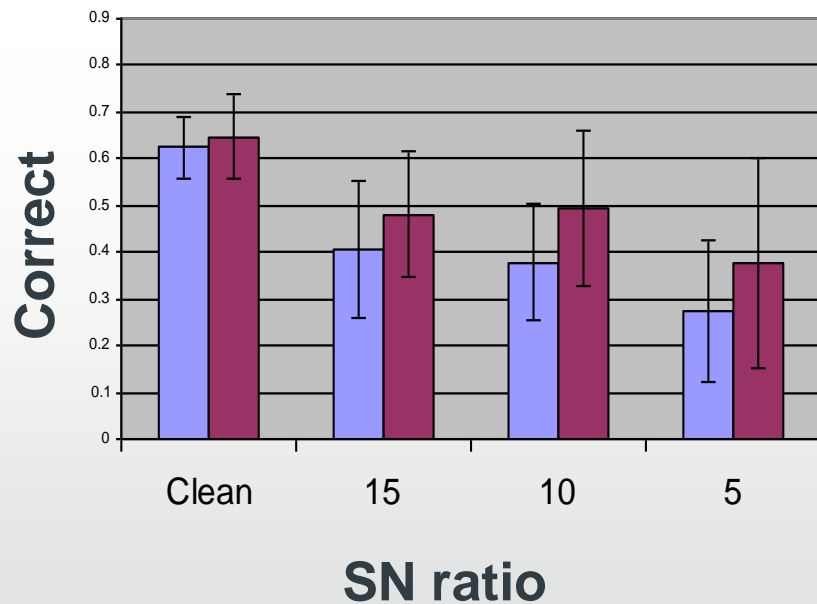
Subjective feed back: Those who benefited from the sparse algorithm reported that the sound is more crisp and clear, especially in noisy conditions !!

Results

For subjects whose performance in quiet lower than 70%:

Modulated babble noise

Stationary babble noise



Discussion of SPARSE results

- Effects of acclimatisation
- *Sparse vs compact* representation
- Threshold parameters : fixed, set for each user, user-adjustable

Looking to the future

- The main limitation on cochlear implant signal processing at present is our *restricted thinking!*
- We must remove the shackles of traditional signal representation (spectrogram, Fourier Transform) and think about what our hearing system is trying to achieve
- Consideration of *information* (or *entropy*) provides an alternative way of thinking about the problem
- These ideas are already being explored in vision science
- Other new ways of thinking may prove even more productive