Medical Signal Analysis in Visual Signal

Yetmen Wang
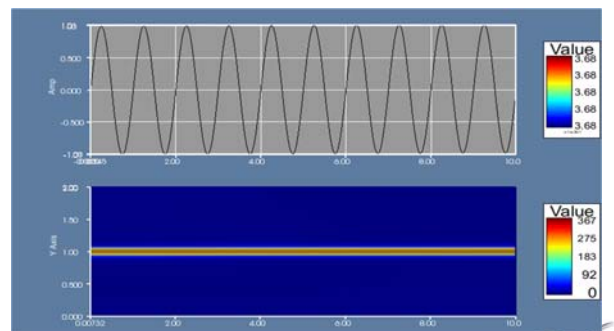AnCAD, Inc.

Contents

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- Complexity, Multi-Scaled Entropy, 渾沌
  - Brain wave
- Independent Component Analysis
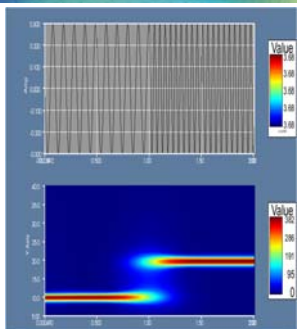

What is time-frequency analysis?

TF Plot: Single frequency

TF Plot: Change of frequency
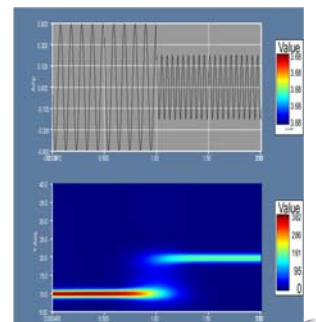
- Signal with abrupt change of frequency.

$$x(t) = \begin{cases} 0.30\cos(2 \times 10\pi t) & ,0 \le t < 1 \\ 0.30\cos(2 \times 20\pi t) & ,1 \le t < 2 \end{cases}$$

TF Plot: Change of frequency and amplitude

- Signal with abrupt change of frequency and amplitude

$$x(t) = \begin{cases} 0.30\cos(2 \times 10\pi t) & ,0 \le t < 1 \\ 0.15\cos(2 \times 20\pi t) & ,1 \le t < 2 \end{cases}$$

Time-Frequency Analysis Comparison

	Fourier Transform	STFT	Morlet / Enhanced Morlet	Hilbert Transform	HHT
Instantaneous frequency	n/a	distribution	distribution	Single value	Discrete values
Frequency change with time	no	yes	yes	yes	yes
Frequency resolution	good	ok	ok/good	good	good
Adaptive base	no	no	no	n/a	yes
Handling non-linear effect	n/a	no	no	yes	yes

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Morlet transform

- Morlet transform on a chirp signal.
- In catching the high frequency spectrum, mother wavelet of short duration of time is used. The spectrum of such wavelet suffers from wide span of frequency, resulting in low resolution, as shown in the right left plot.

*AnCAD*
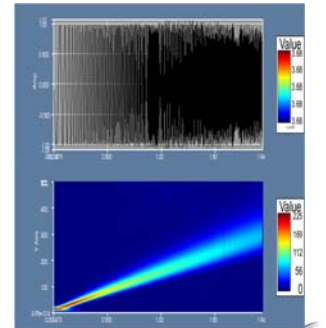
Enhanced Morlet Transform

- By applying Gaussian windowing in frequency domain and knowing that the crossed term of convolution between mother wavelet and signal is the cause of blur, the resolution of Morlet transform can be greatly improved by neglecting the crossed term.
- The fine structure appears in high frequency region is caused by under sampling. The chirp signal is digitized with constant sampling rate.
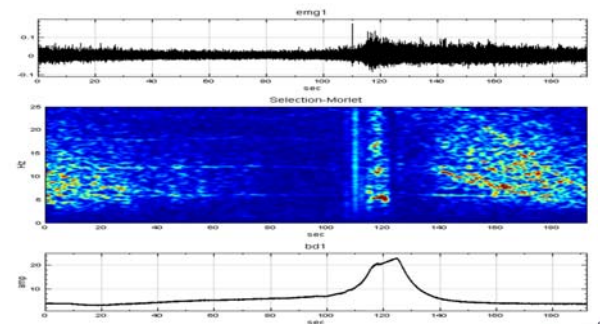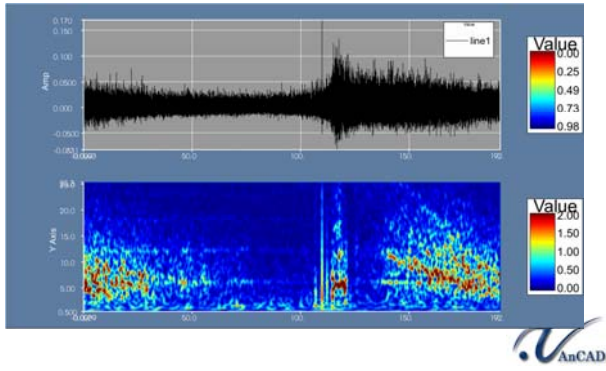

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EMG: Bladder signal analysis

AnCAD
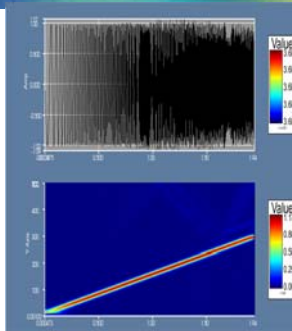
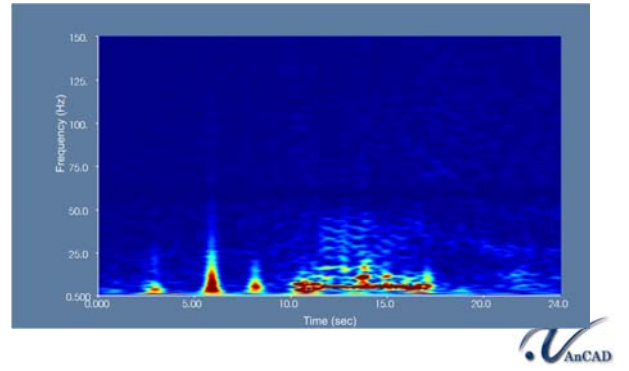## Bladder signals (pressure and EMG)

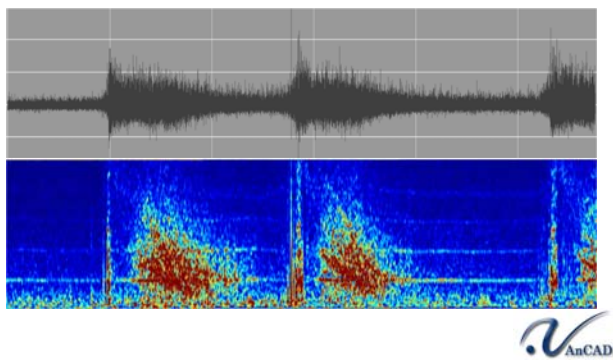*AnCAD*

Time-frequency analysis

AnCAD
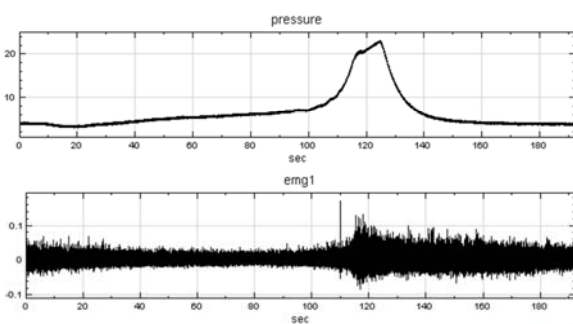
EMG signal of a bladder during urination

EMG signal of a bladder during urination (log scale)

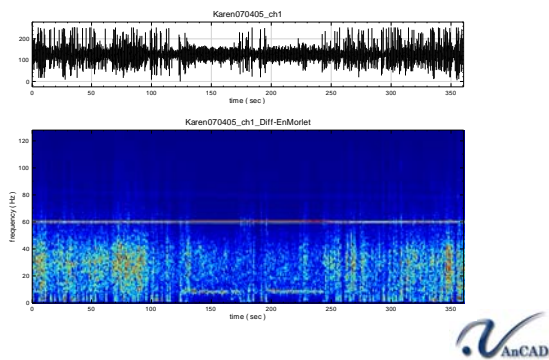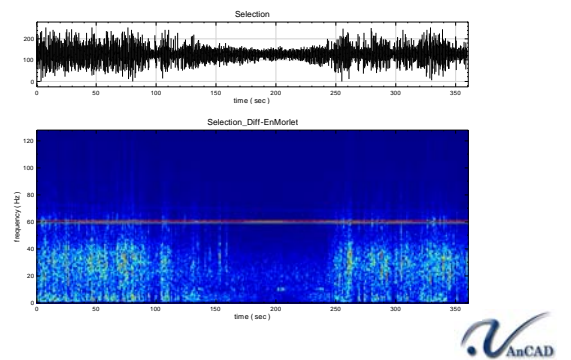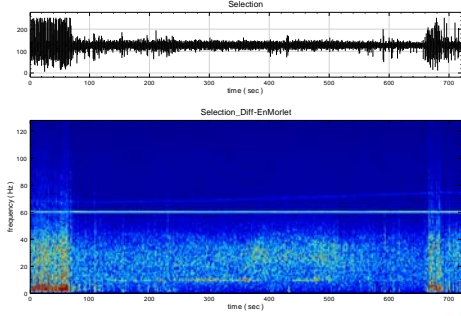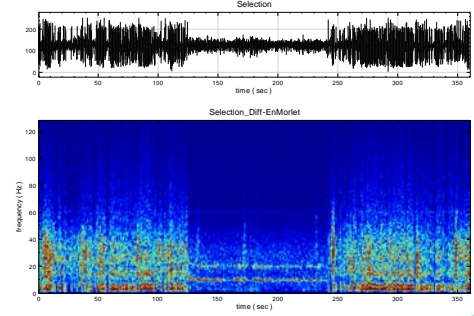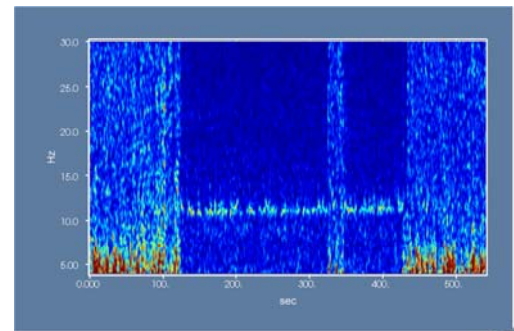Whole cycle

Brain wave

靜心（Karen070405_ch1）

靜心（Mano070405-ch1）

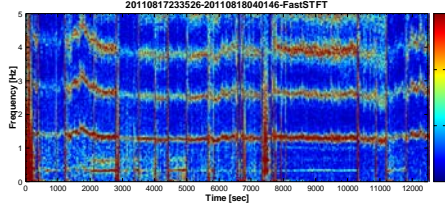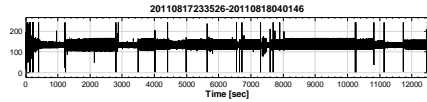静心（余雪鴻_ch1）

静心（唐長笙_ch1）

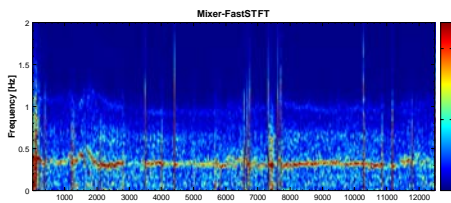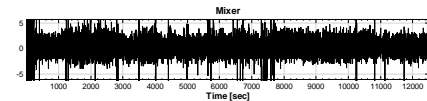焦慮（SU0221_ch1）
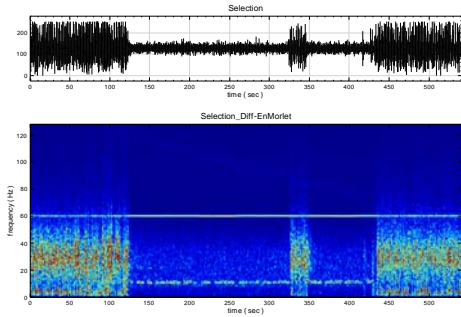
光波引導_ch1
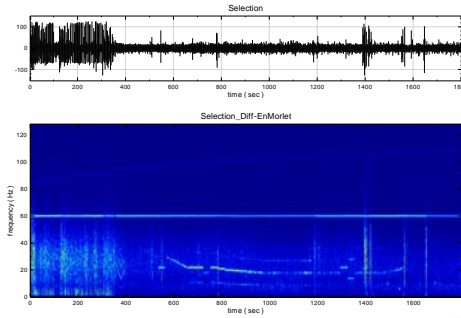
ECG AND RESPIRATION

ECG

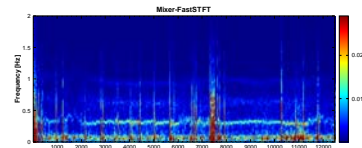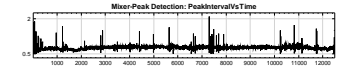## Envelope detection
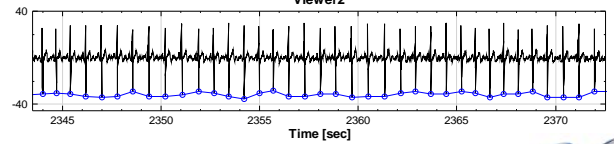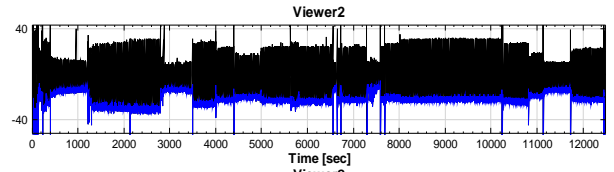
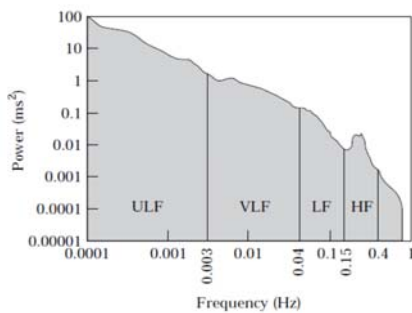## Time-frequency plot of envelope signal

Respiration effect on ECG signal emerges as frequency variation over time.

RRI vs. time

Separation of RRI spectrum*

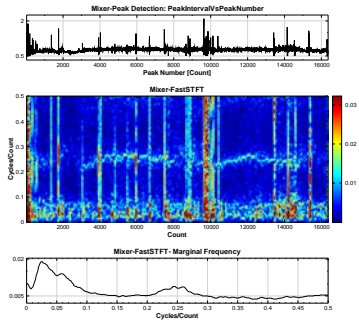*Heart Rate Variability, European Heart Journal (1996) **17，**354-381
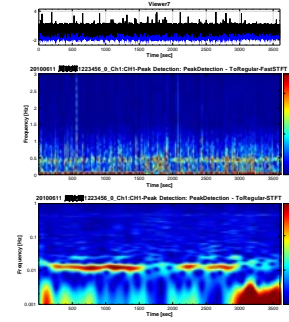
Meaning of RRI Spectrum

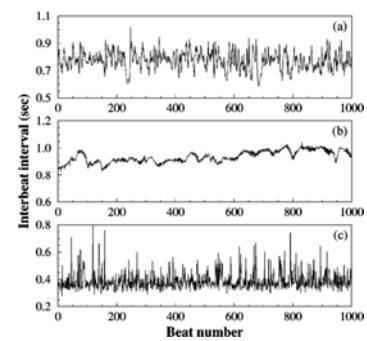| 檢測項目	代表意義
RR Interval Histogram	心跳頻率的變化。
LF(low-frequency power) (0.04 to 0.14 Hz)	低頻，能代表自律神經總體功能。
HF(high -frequency power) (0.15 to 0.4 Hz)	高頻，和呼吸同步，又稱為呼吸成分，代表 副交感神經功能。
LF / HF	交感神經與副交感神經比值。
LF%	交感神經功能。
VLF (0.003 to 0.04 Hz)	unknown
ULF (<0.003Hz)	unknown

30

RRI vs. beat count

Log scaled to detect low frequency

Complexity, Multi-Scaled Entropy, 渾沌

Which one is healthy?*

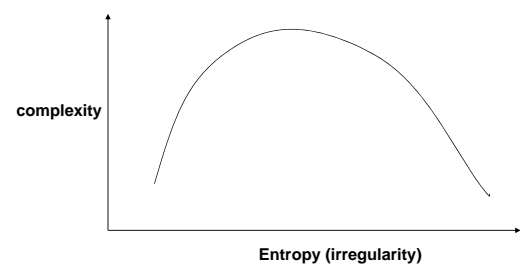***Madalena Costa, Ary L. Goldberger and C.-K. Peng, 2005**

Order vs. Disorder

Healthy

Congestive Heart Failure

Atrial Fibrillation
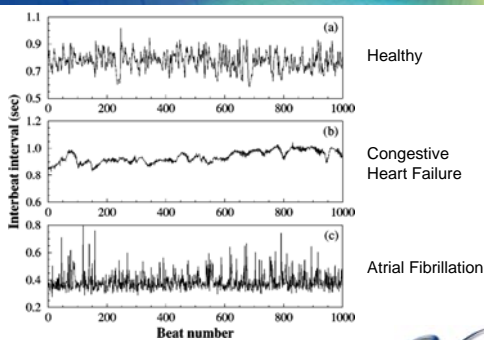
*Madalena Costa, Ary L. Goldberger and C.-K. Peng, 2005

Complexity (health value) vs. Entropy
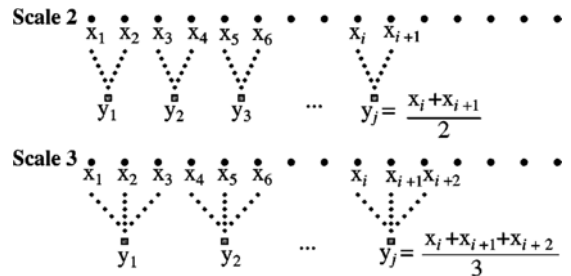

complexity

Entropy (irregularity)

How to define complexity?

- Surface roughness of the Moon results in smooth look from the Earth. => Irregularity will be smoothed out through distant (scaled) perception.
- The irregular shape (fractal or self-similarity structure) of a tree remains the same in spite of distant or close look.
- Multi-Scale perception distinguishes the promethean system from irregularity.
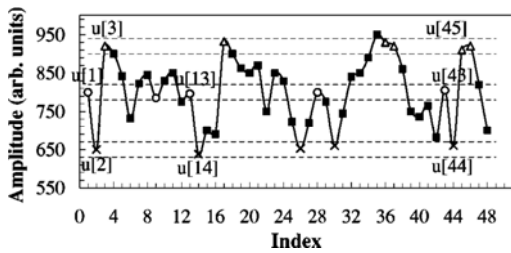
Complexity: Multi-Scale Entropy*

Scale 2: $x_1 \; x_2 \; x_3 \; x_4 \; x_5 \; x_6 \quad x_i \; x_{i+1}$
$y_1 \; y_2 \; y_3 \quad \cdots \quad y_j = \dfrac{x_i + x_{i+1}}{2}$

Scale 3: $x_1 \; x_2 \; x_3 \; x_4 \; x_5 \; x_6 \quad x_i \; x_{i+1} x_{i+2}$
$y_1 \quad y_2 \quad \cdots \quad y_j = \dfrac{x_i + x_{i+1} + x_{i+2}}{3}$

*Madalena Costa, Ary L. Goldberger and C.-K. Peng, 2005

Sample Entropy: Measurement of self-similarity*

SE: the probability of which matching of two consecutive points suggests matching of three consecutive points.
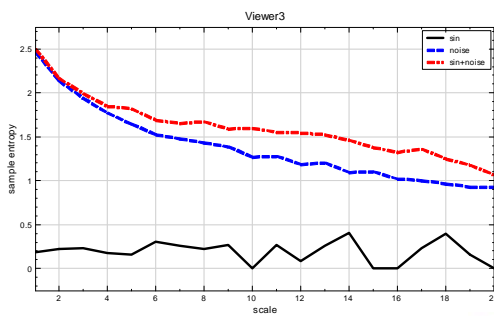
*Madalena Costa, Ary L. Goldberger and C.-K. Peng, 2005

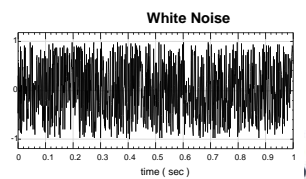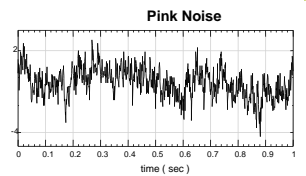## Order vs. disordered
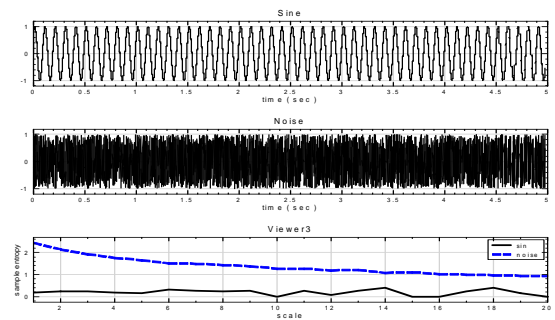
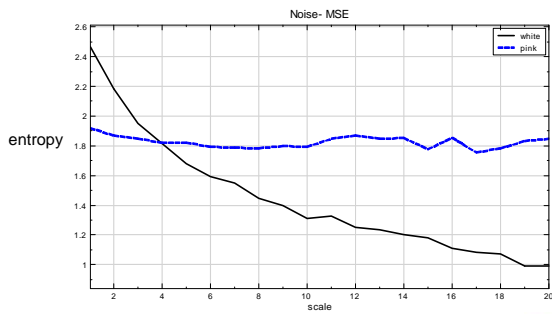## Mixed signal increases complexity

White Noise vs. Pink (1/f) Noise

- Pink noise
  - Correlated signal
  - Low frequency with high amplitude
- White noise
  - Uncorrelated
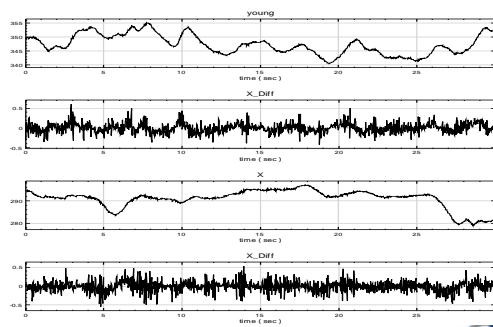 - Amplitude the same whatever the frequency is
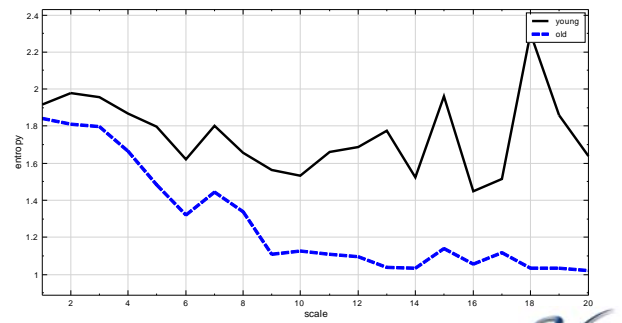
MSE: white vs. pink

Center of Pressure Sway

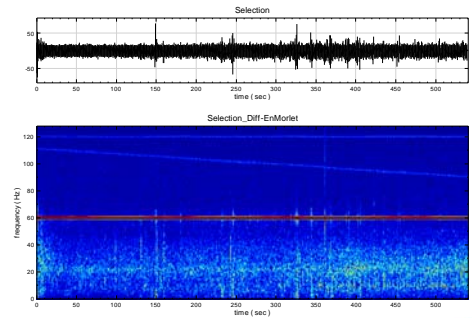## COP Sway of the Young and the elderly

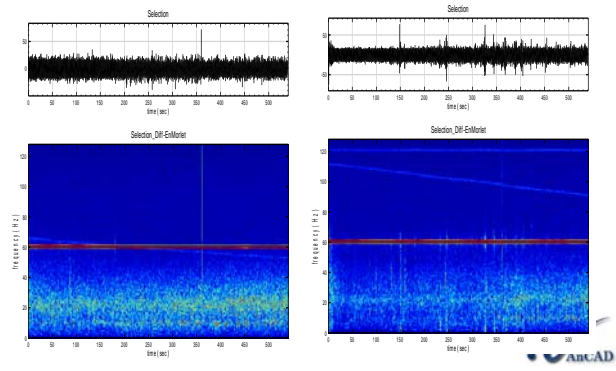## MSE Analysis of COP Sway

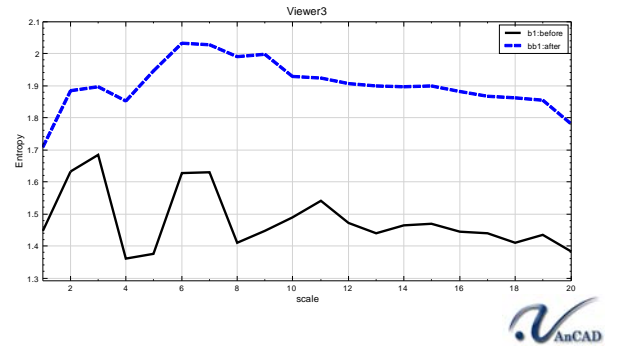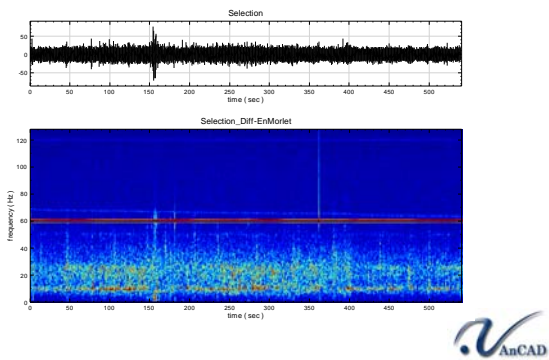## Increase of complexity in brain wave signal after days of meditation
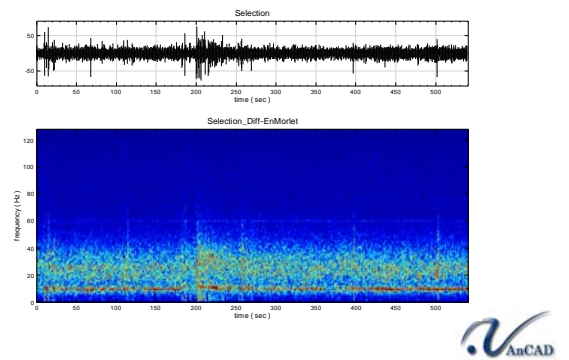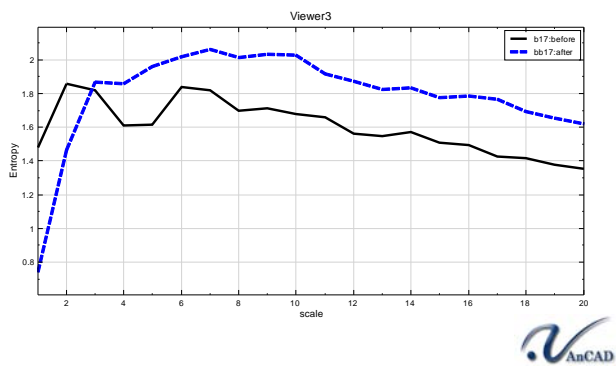
b1

Bb1 vs b1

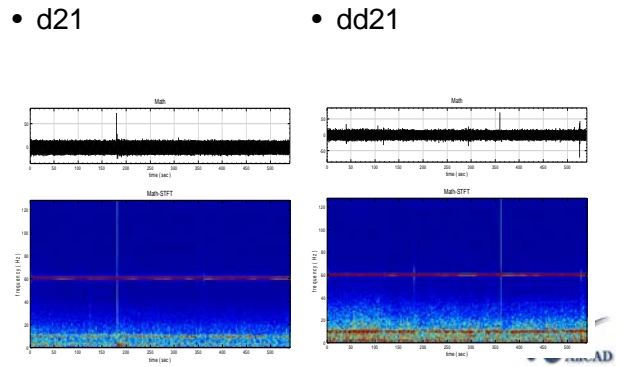
Complexity (MSE)
Before and After Meditation

b17

bb17

Complexity (MSE)
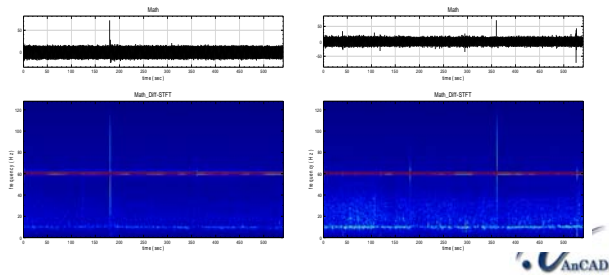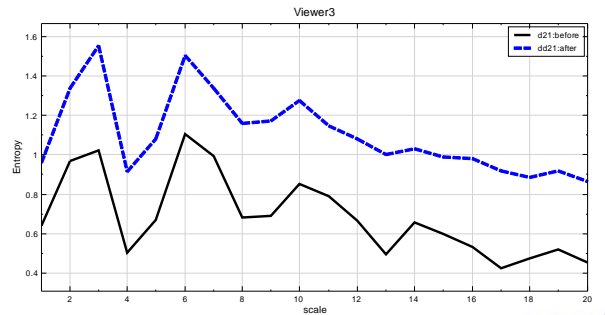Before and After Meditation

- d21
- dd21

differential

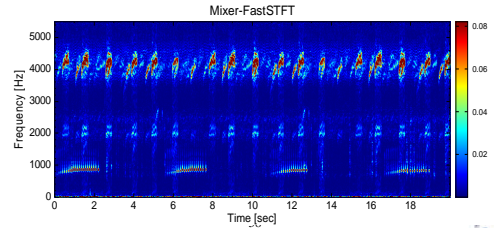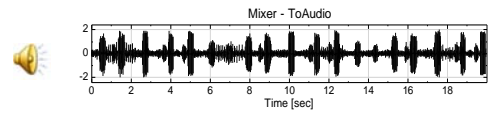• d21   • dd21

Complexity (MSE)
Before and After Meditation

Independent Component Analysis

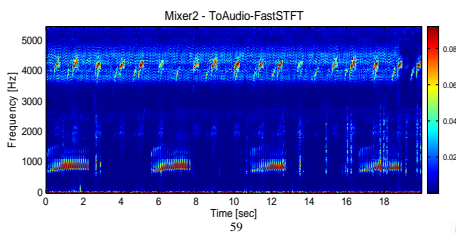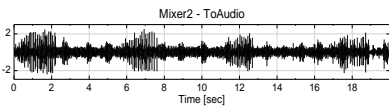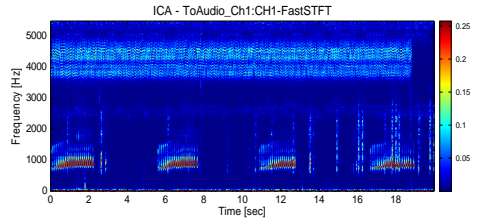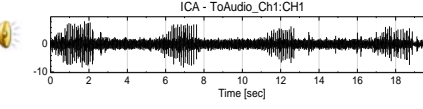－獨立成分分析(ICA)－

生態監測（Microphone I）

－獨立成分分析(ICA)－

生態監測（Microphone II）

－獨立成分分析(ICA)－

After ICA （豎琴蛙）

－獨立成分分析(ICA) －

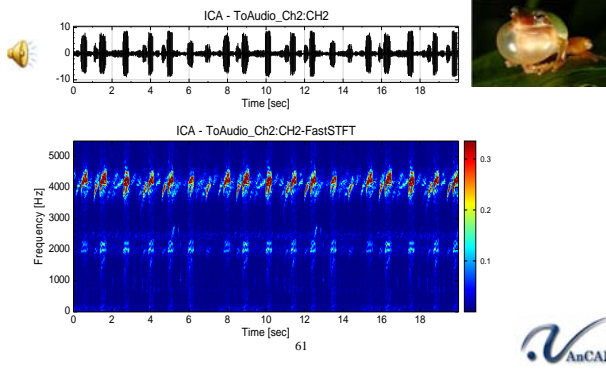### After ICA （中國樹蟾）

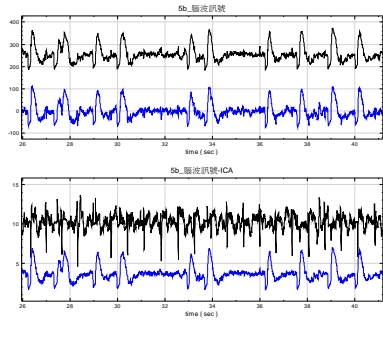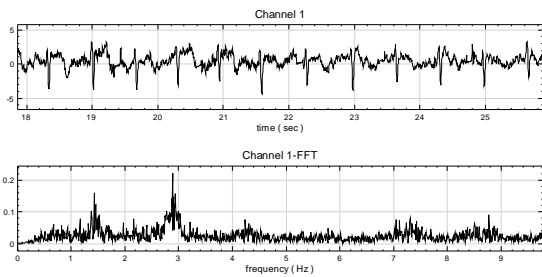## Brain wave separation

Heart Beat Signal Separation

Thank you!