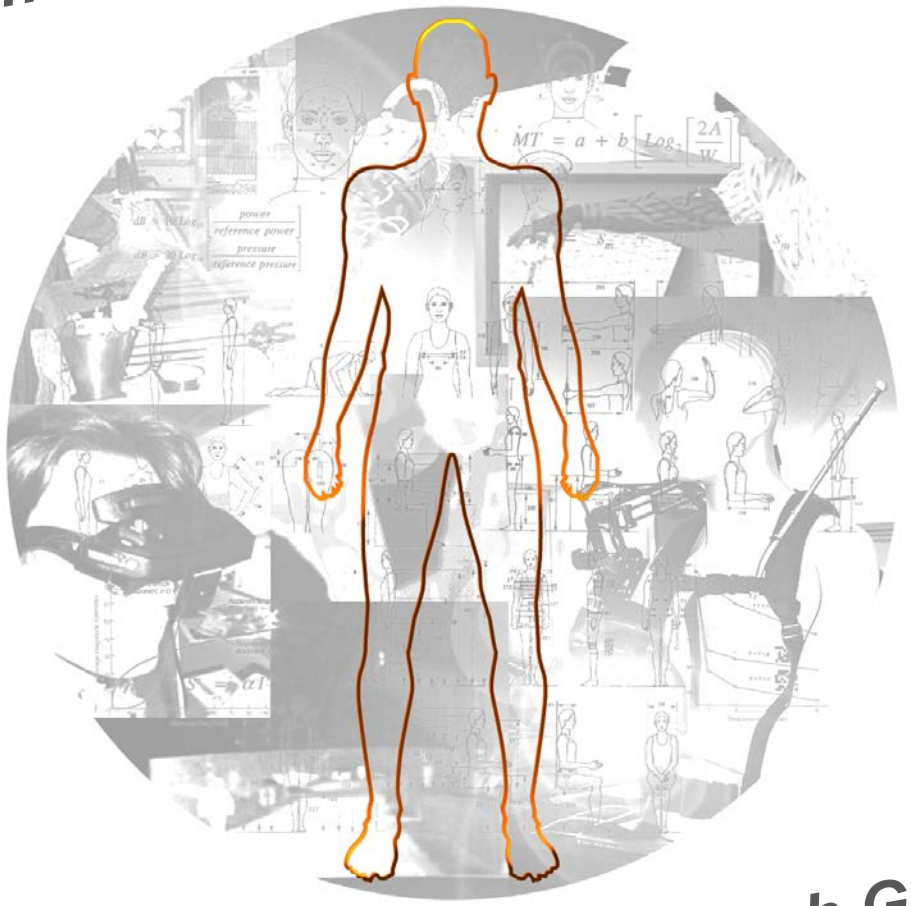
Perception Enhancement for Automotive Steering Systems



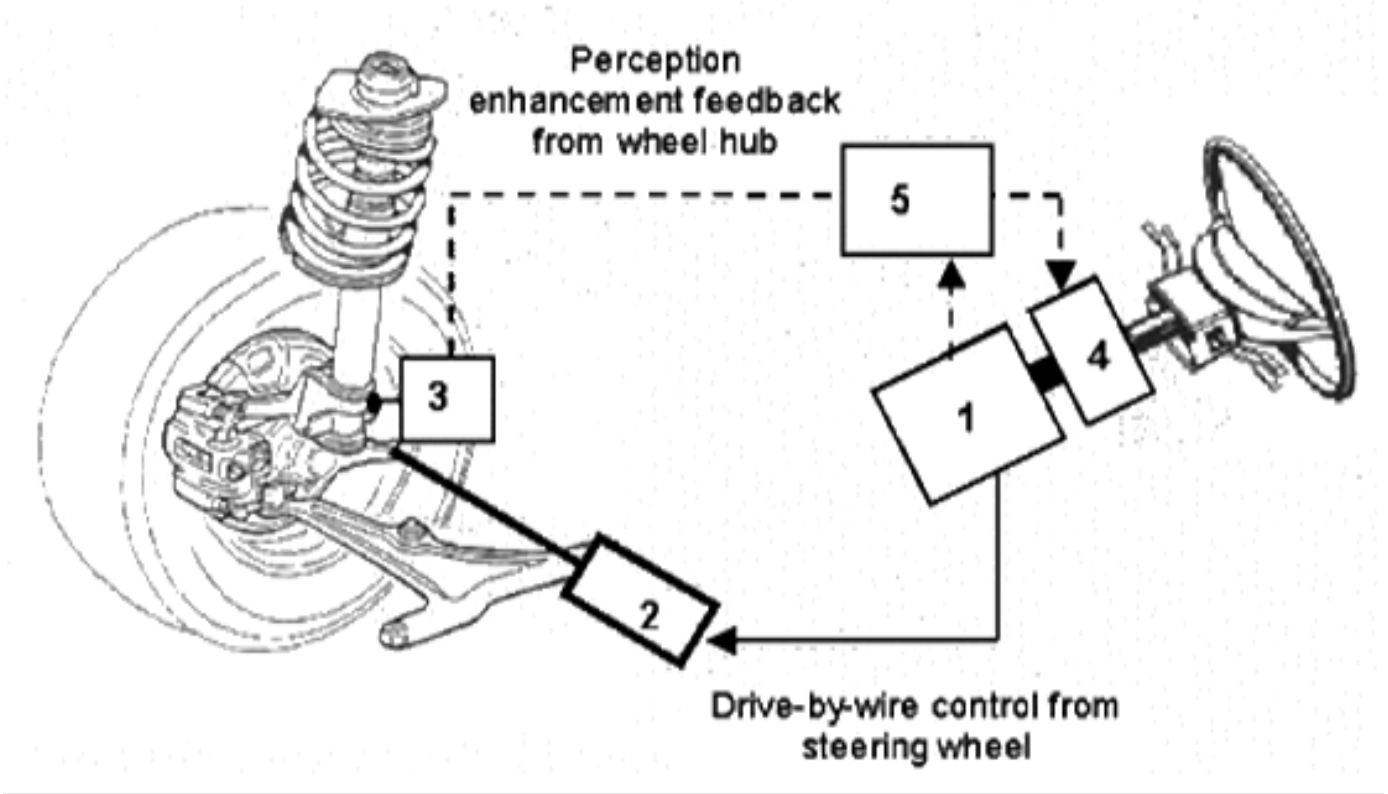
Prof. Joseph Giacomin

November 13th 2013

Perception Enhancement

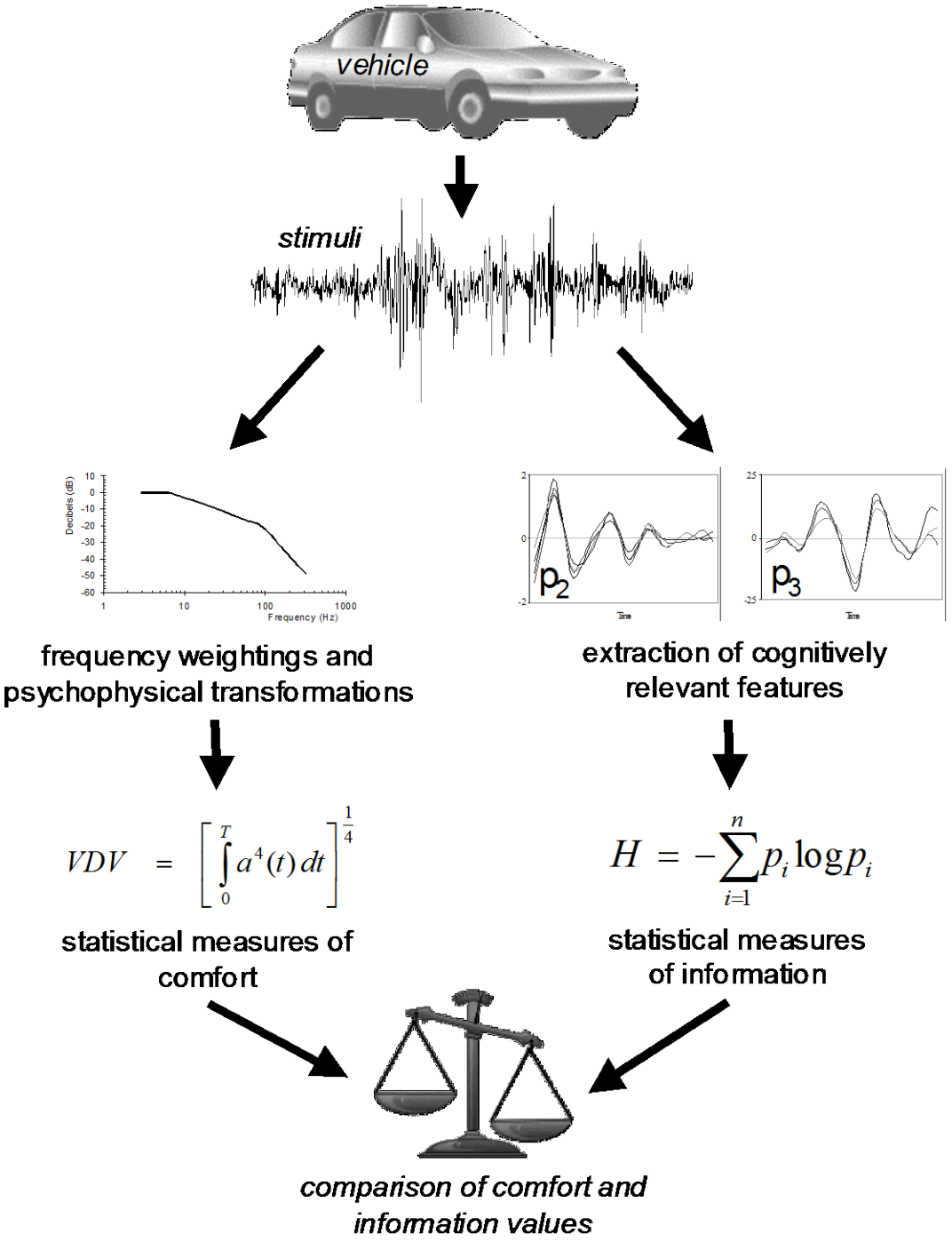
In the 21st century digital signal processing has made it possible to decode the natural languages of many animals and environments. These same methods can decode the sound, vibration and other stimuli of automobiles, permitting the design of controls and emissions which enhance the communication between the automobile and the driver.

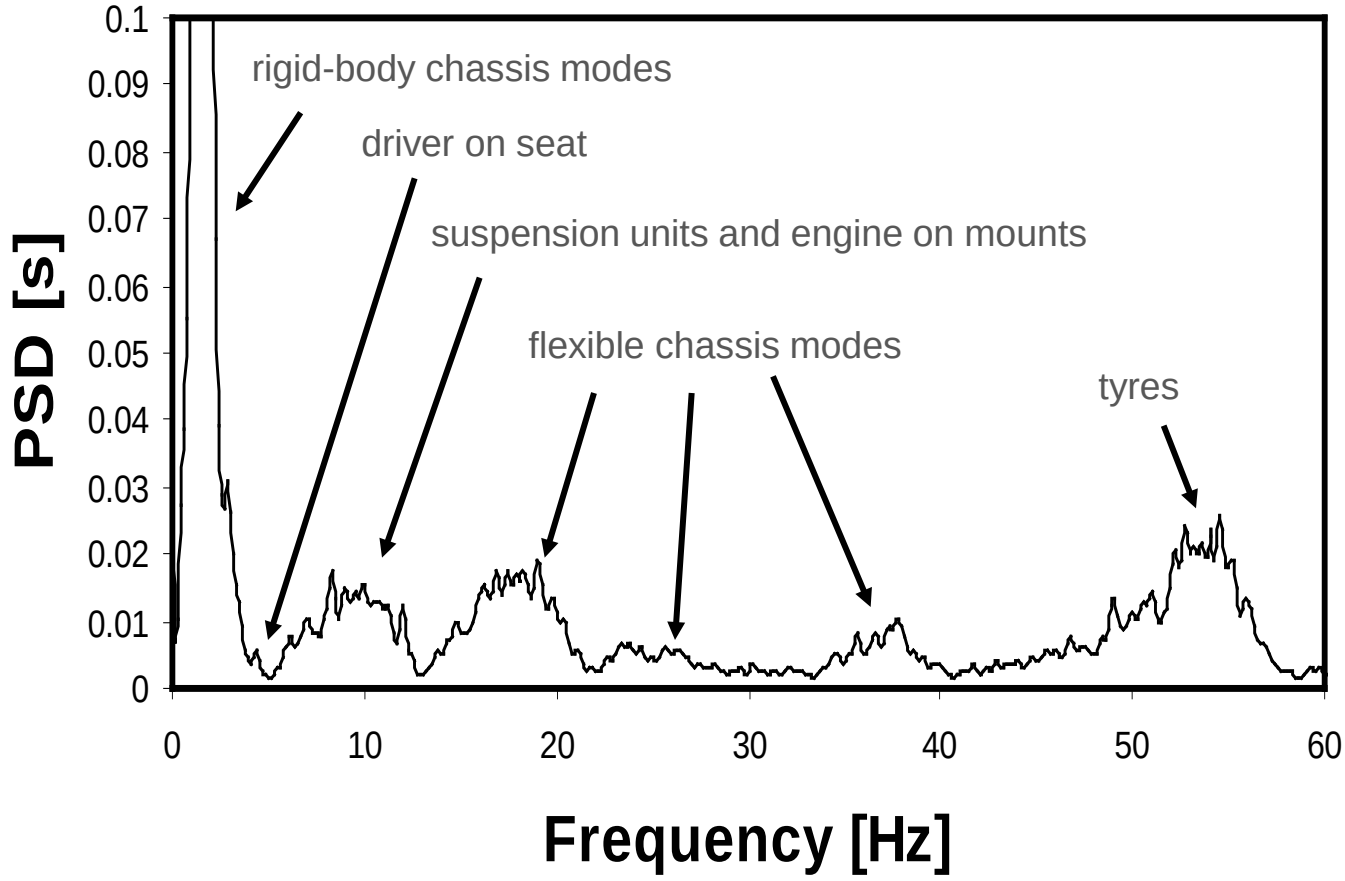
Perception Enhancement Systems



The term *Perception Enhancement System* can be used to describe any device which optimises the feedback of environmental or vehicle stimuli to the driver.

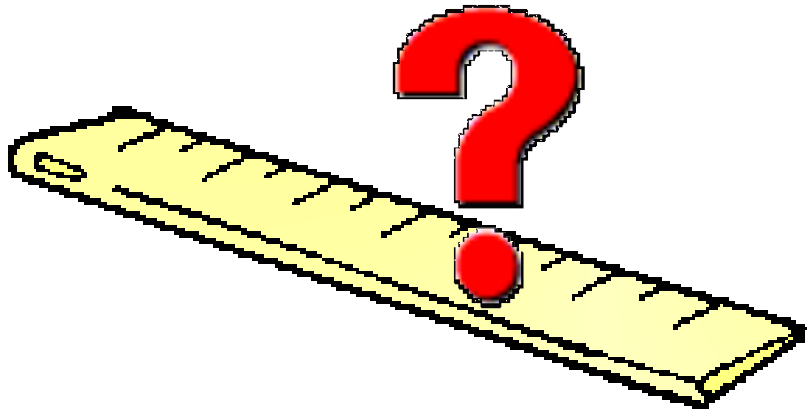
Comfort versus Information





Information from Vibration

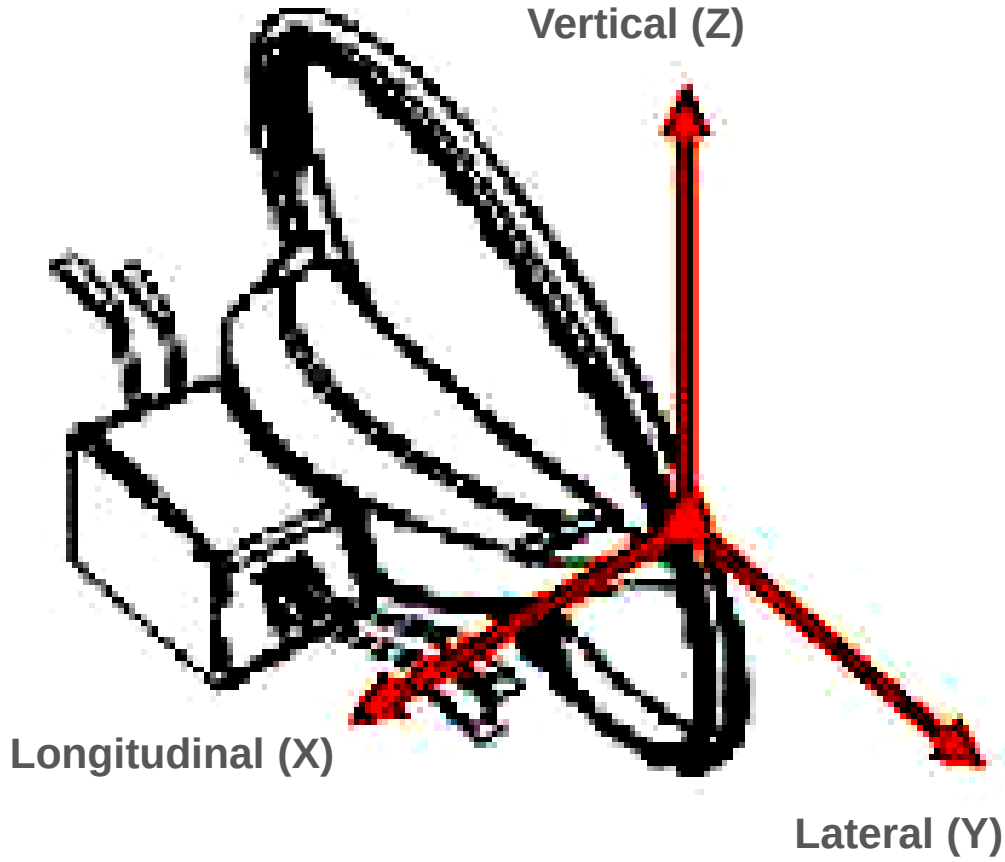
From a perception enhancement point of view the vibrational inputs from the road surface and the resonance behaviours of the vehicle subsystems are sources of information. The example above is a vertical seat guide acceleration signal measured at the seat rail mounting bolt in a Renault automobile.



Research Aims

- **To investigate the human ability to identify road surfaces based on the tactile stimuli (vibration) of the steering wheel.**

- **To determine, based on the human responses, if different road surfaces require different perception enhancement strategies.**

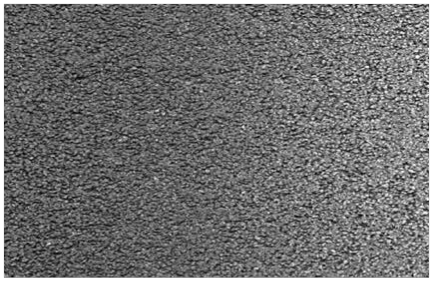


Steering Vibration

Measurements of steering wheel acceleration were made using a triaxial accelerometer attached to a mounting block. The tangential acceleration (Z direction) was chosen for use in the laboratory experiments.

Test Roads

Tarmac road (vehicle speed : 96kph)

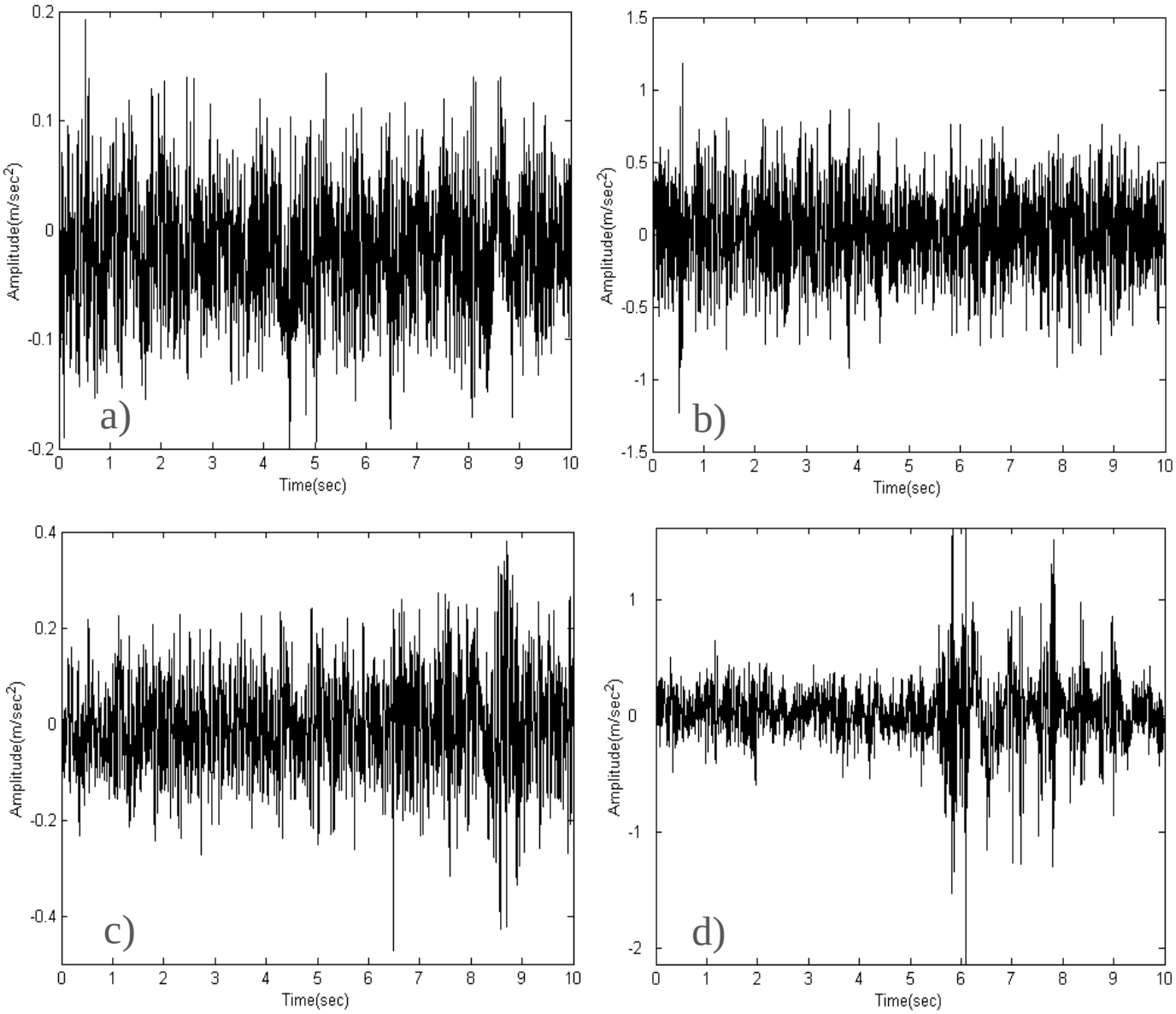


Cobblestones road (vehicle speed : 30kph)

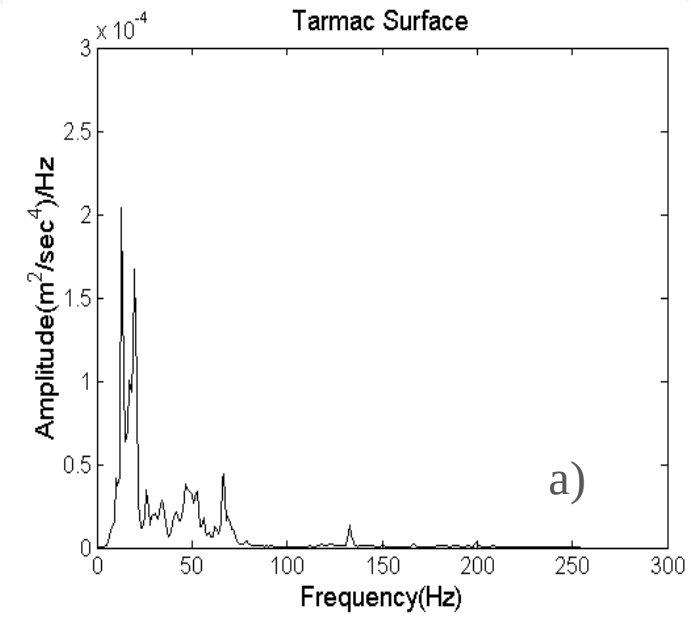
Concrete road (vehicle speed : 96kph)

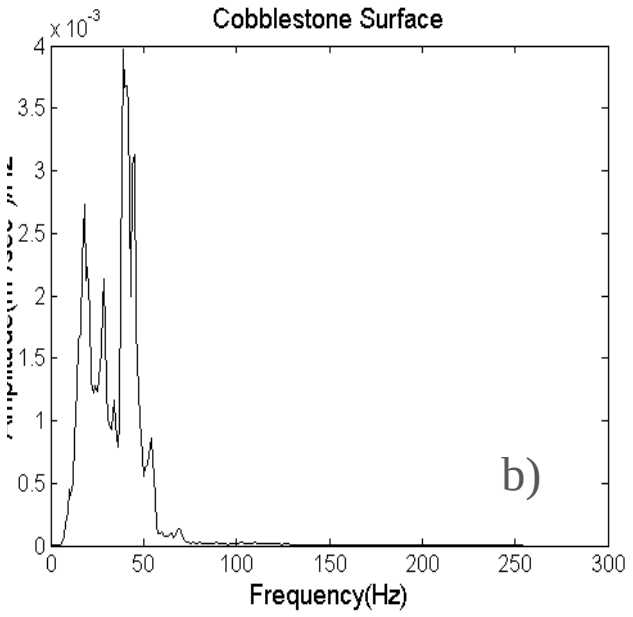
Bump road (vehicle speed : 50kph)

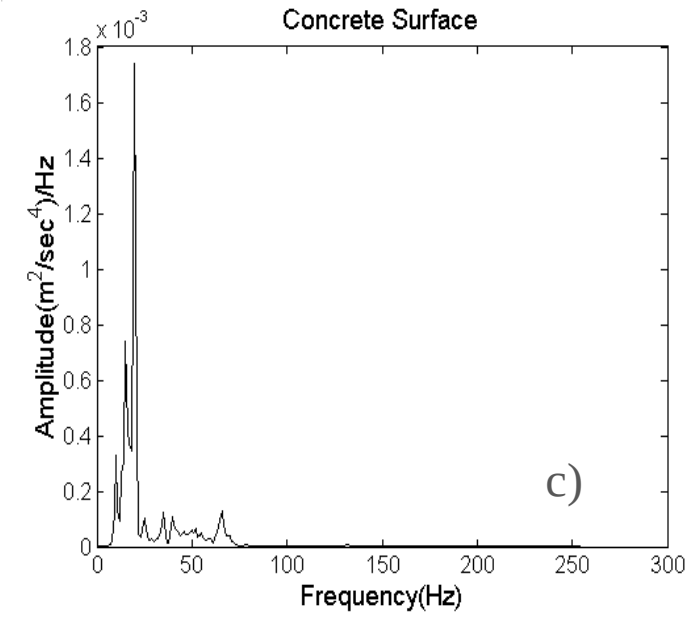
Test Roads

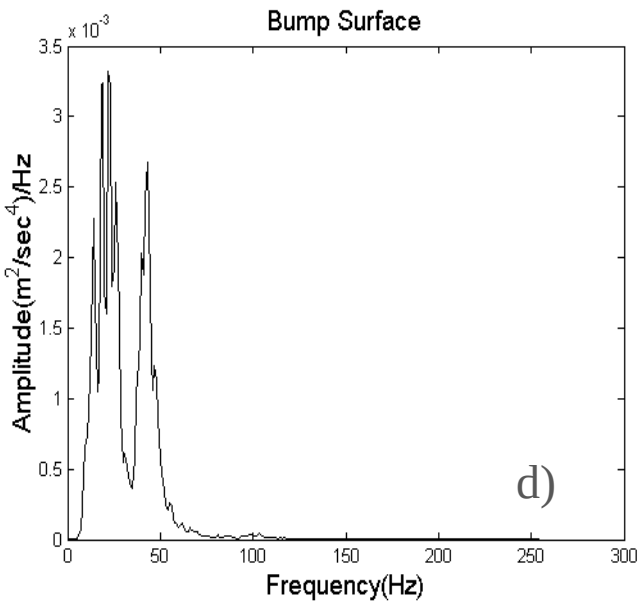


Test Roads

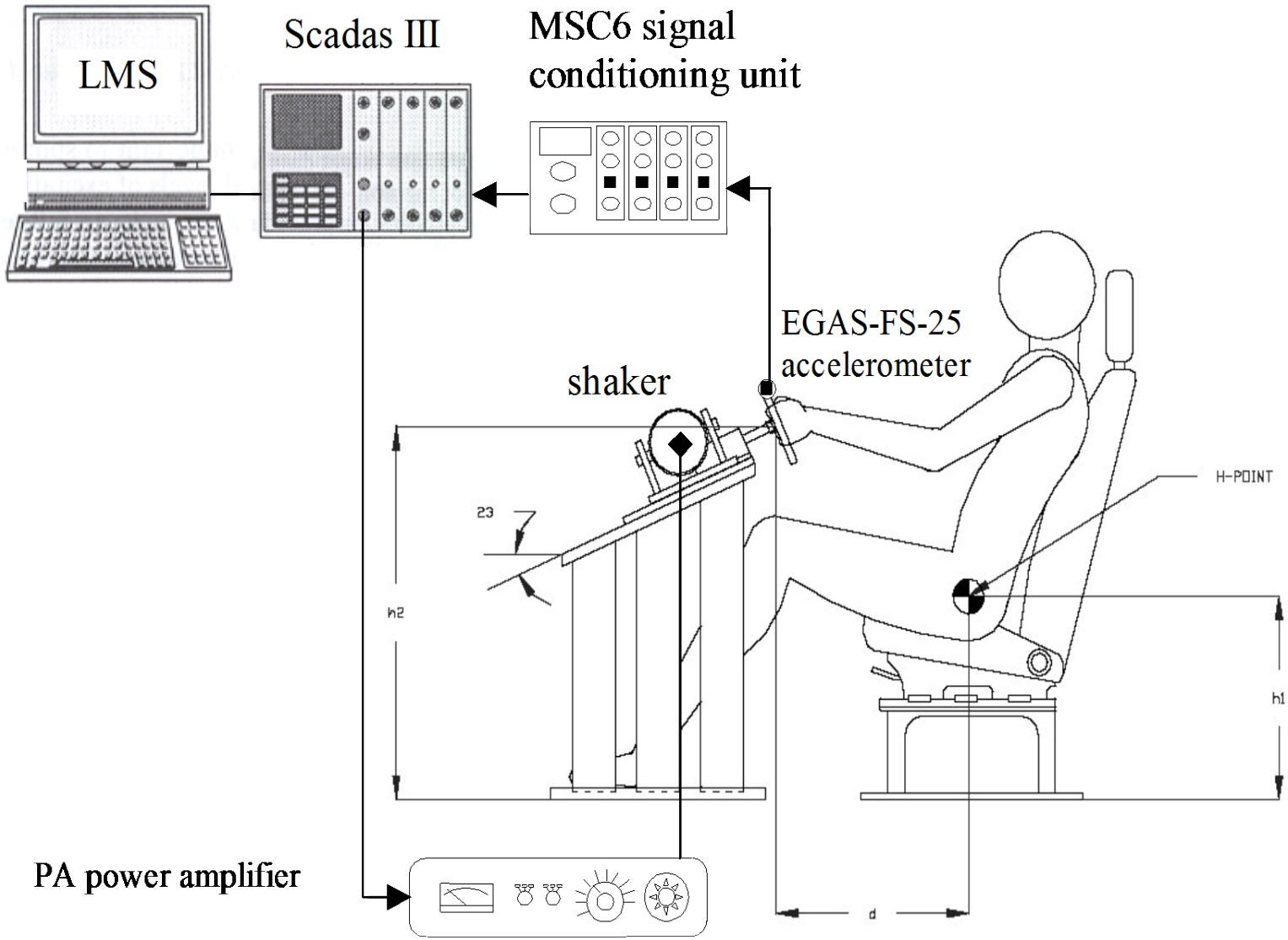

Tarmac Surface
x 10^-4
Amplitude(m^2/sec^4)/Hz
Frequency(Hz)
a)


Cobblestone Surface
x 10^-3
Frequency(Hz)
b)


Concrete Surface
x 10^-3
Amplitude(m^2/sec^4)/Hz
Frequency(Hz)
c)


Bump Surface
x 10^-3
Amplitude(m^2/sec^4)/Hz
Frequency(Hz)
d)

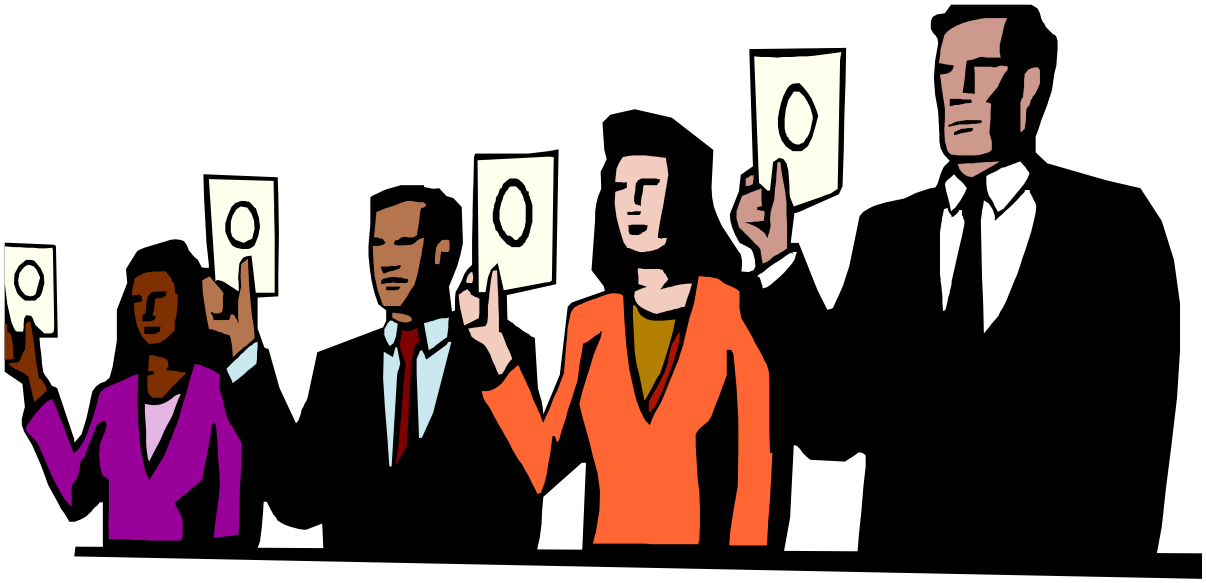
Steering Vibration Test Facility



Road Surface Detection

A large photograph was shown which was similar to the view which would be seen through the front window of the automobile.

For each stimulus the person was asked to indicate whether it was, or was not, from the road of the photograph.



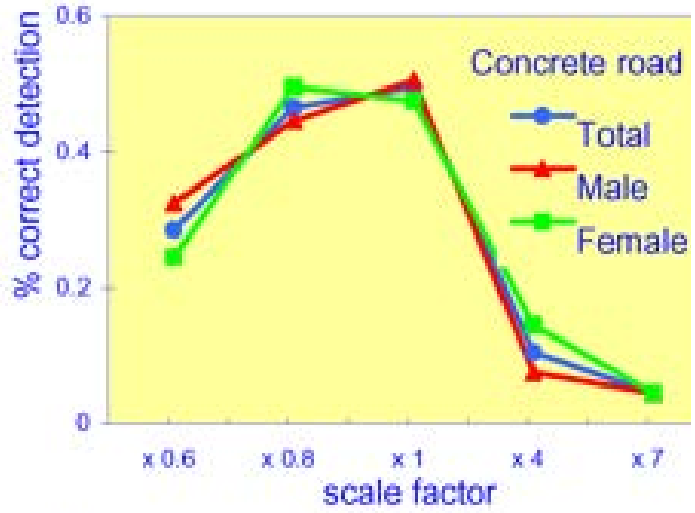
Test Participants

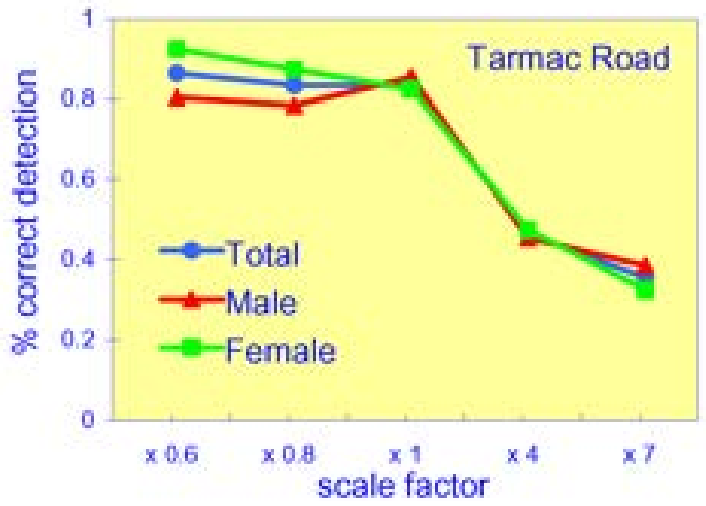
Each test involved a group of university staff and students.

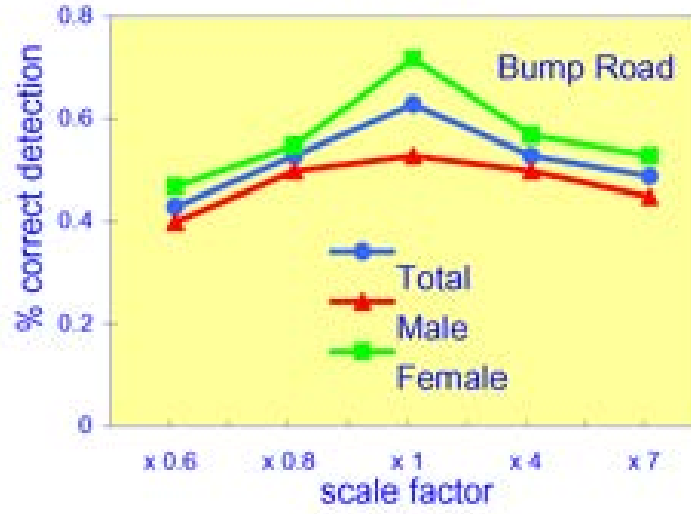
The age, height and mass of each participant was recorded so as to monitor that the physical characteristics of each test group were close to the 50 percentile values for the UK population.

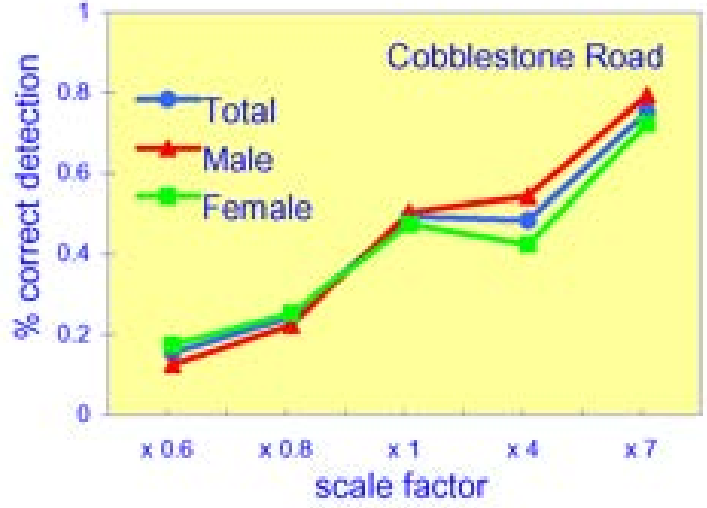
Each participant was asked to state if he or she suffered any medical condition which might effect the perception of vibration or sound. Also, factors which are known to effect the human perception of vibration and sound such as smoking or drinking coffee were also recorded.

Effect of Scale/Gain

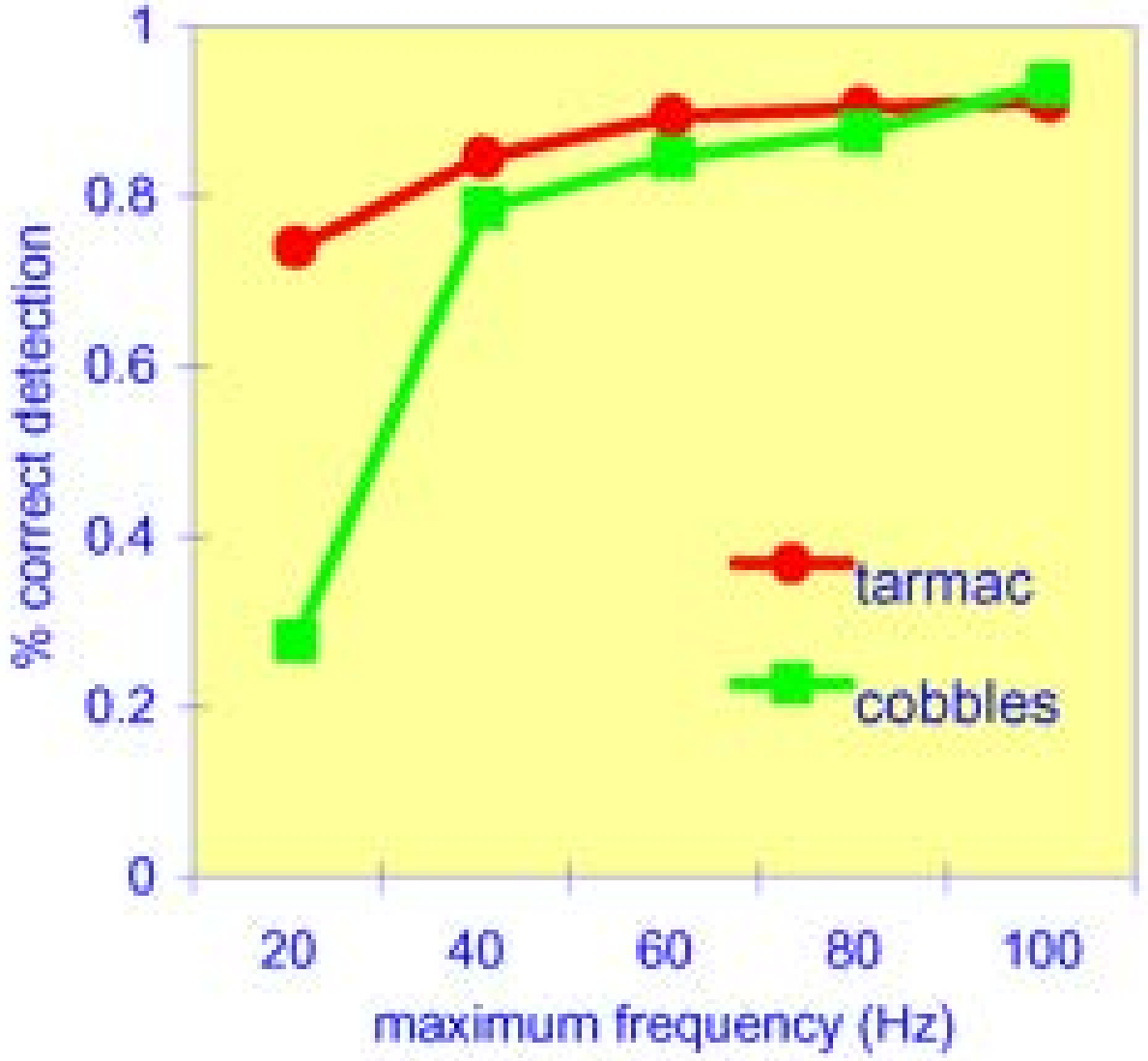






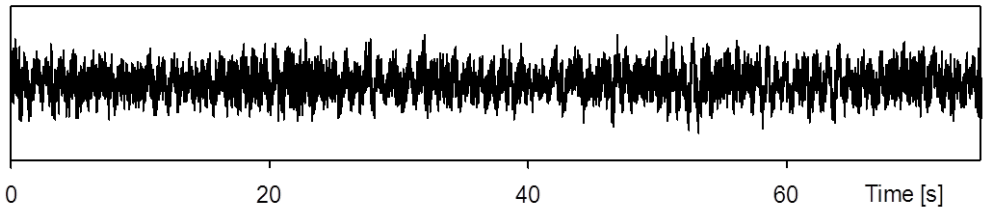


Effect of Frequency Bandwidth

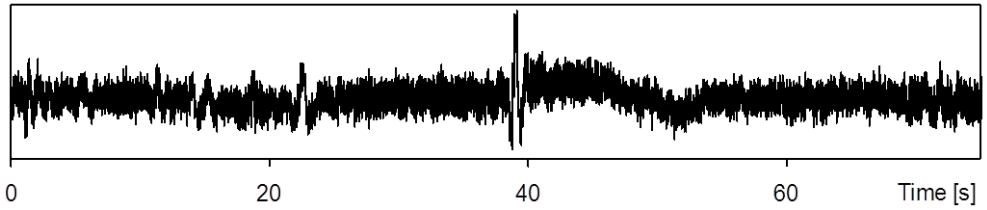


Mildly Nonstationary Mission Synthesis (MNMS)

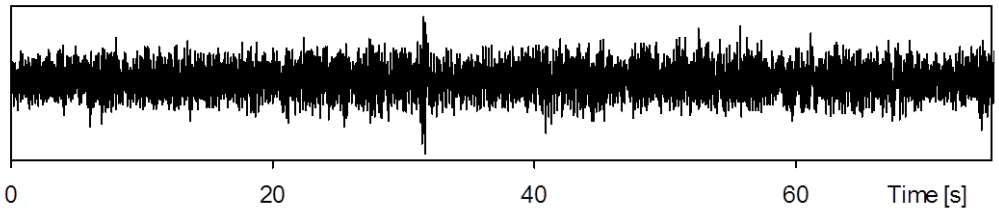
The Mildly Nonstationary Mission Synthesis (MNMS) algorithm was developed based due to the observation that most road surfaces produce mildly nonstationary vibration.



stationary Gaussian signal with kurtosis = 3.04 (Highway Surface)



heavily nonstationary signal (Good Surface with a Climb)

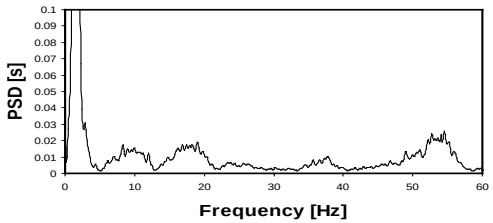


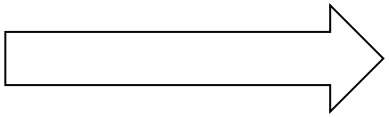
mildly nonstationary signal with kurtosis = 3.23 (Speed Circuit Surface)

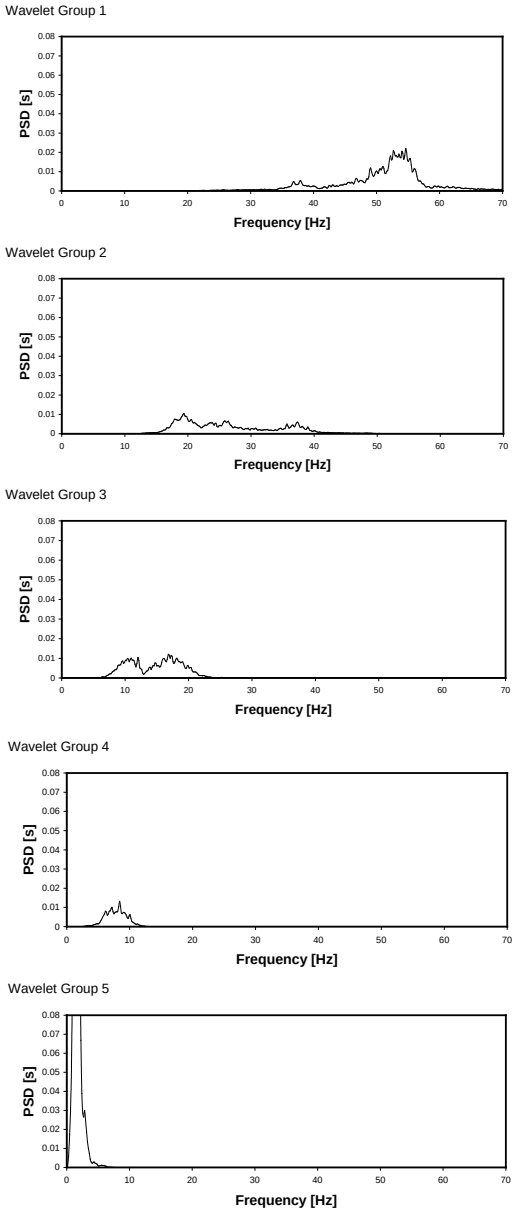
Mildly Nonstationary Mission Synthesis (MNMS)

The Mildly Nonstationary Mission Synthesis (MNMS) algorithm was developed to break signals down in terms of information.

MNMS works in frequency bands which are defined by the user, so as to isolate the individual frequency regions which contain useful information.

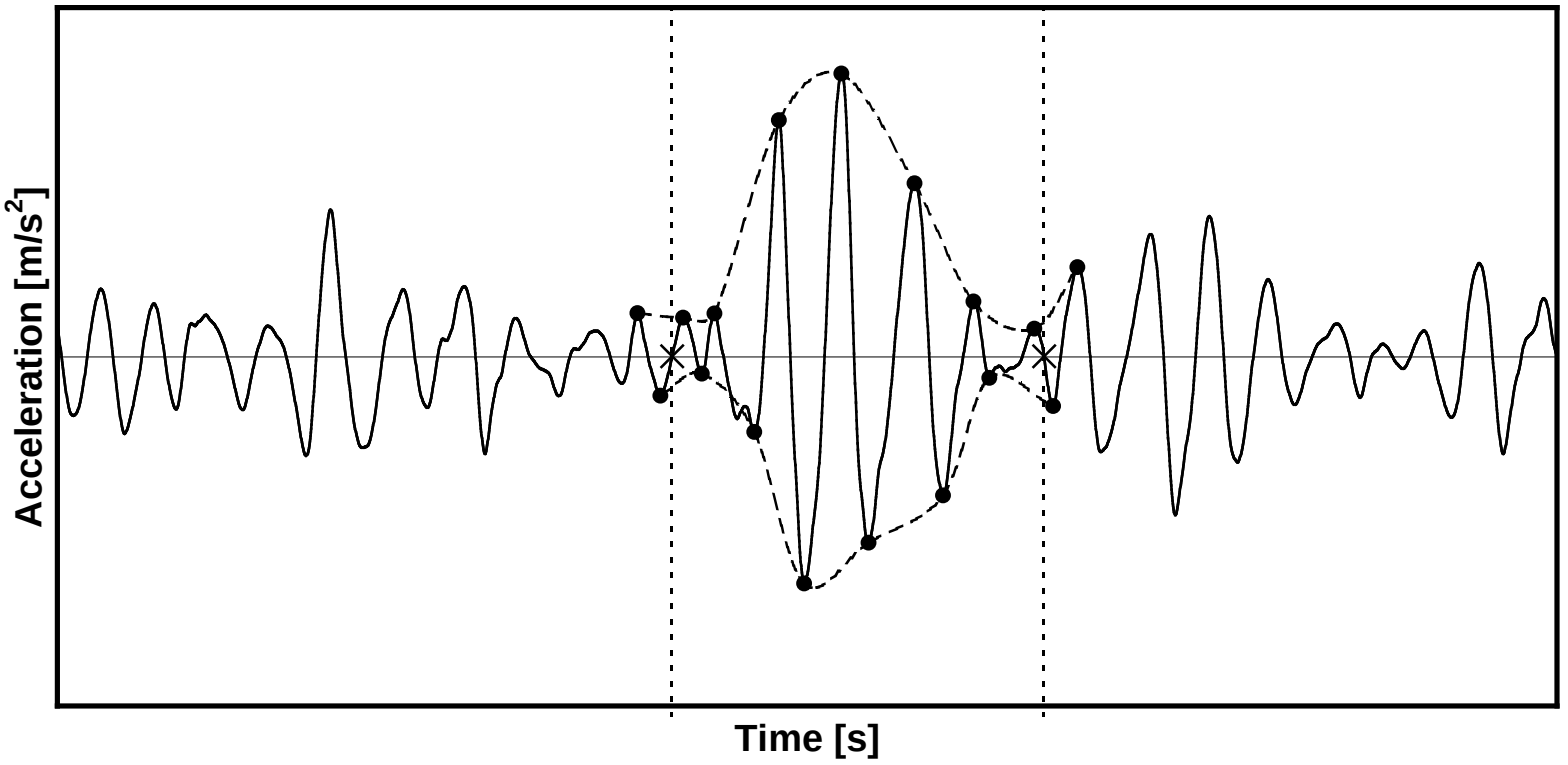






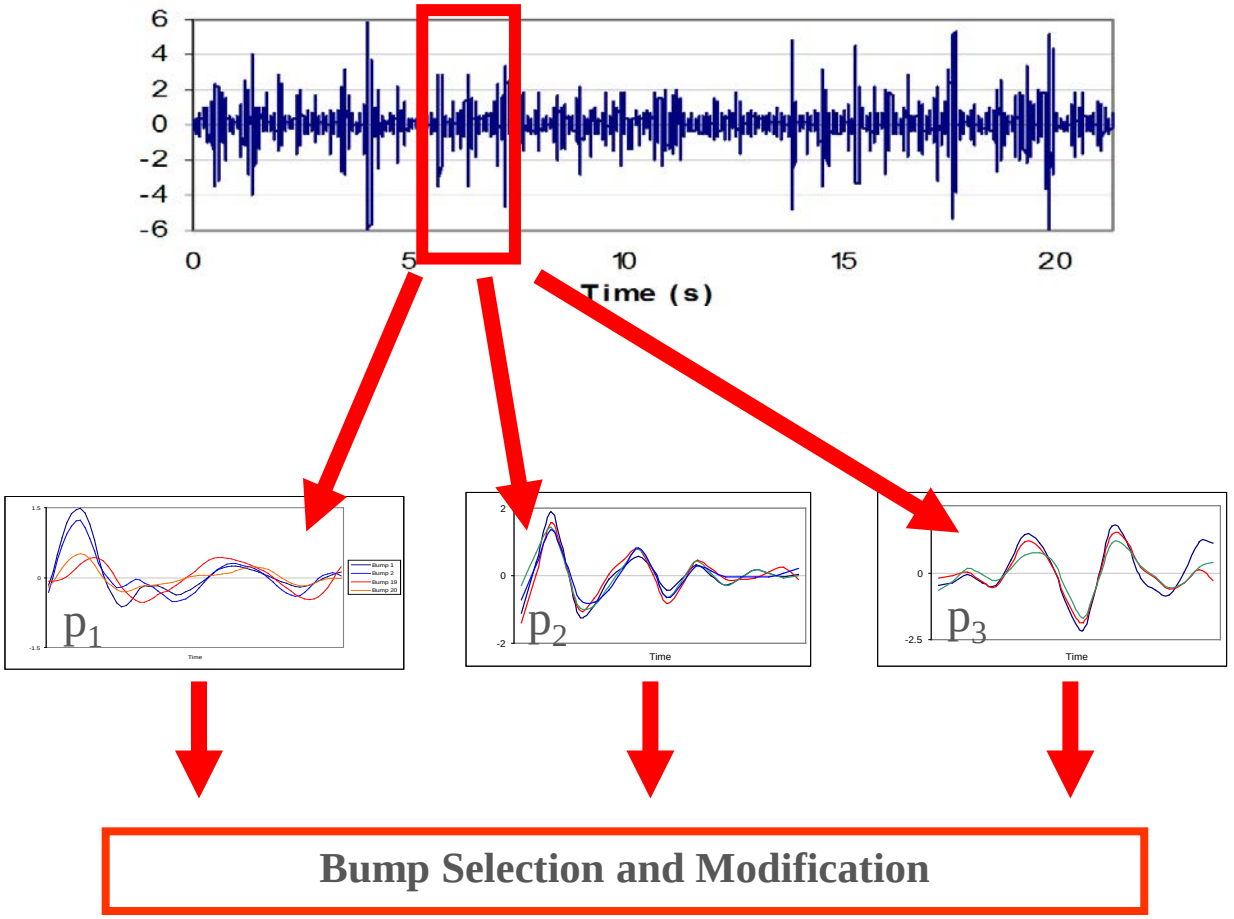
Mildly Nonstationary Mission Synthesis (MNMS)

MNMS searches for short transients and saves the library of individual “bump” events.



Mildly Nonstationary Mission Synthesis (MNMS)

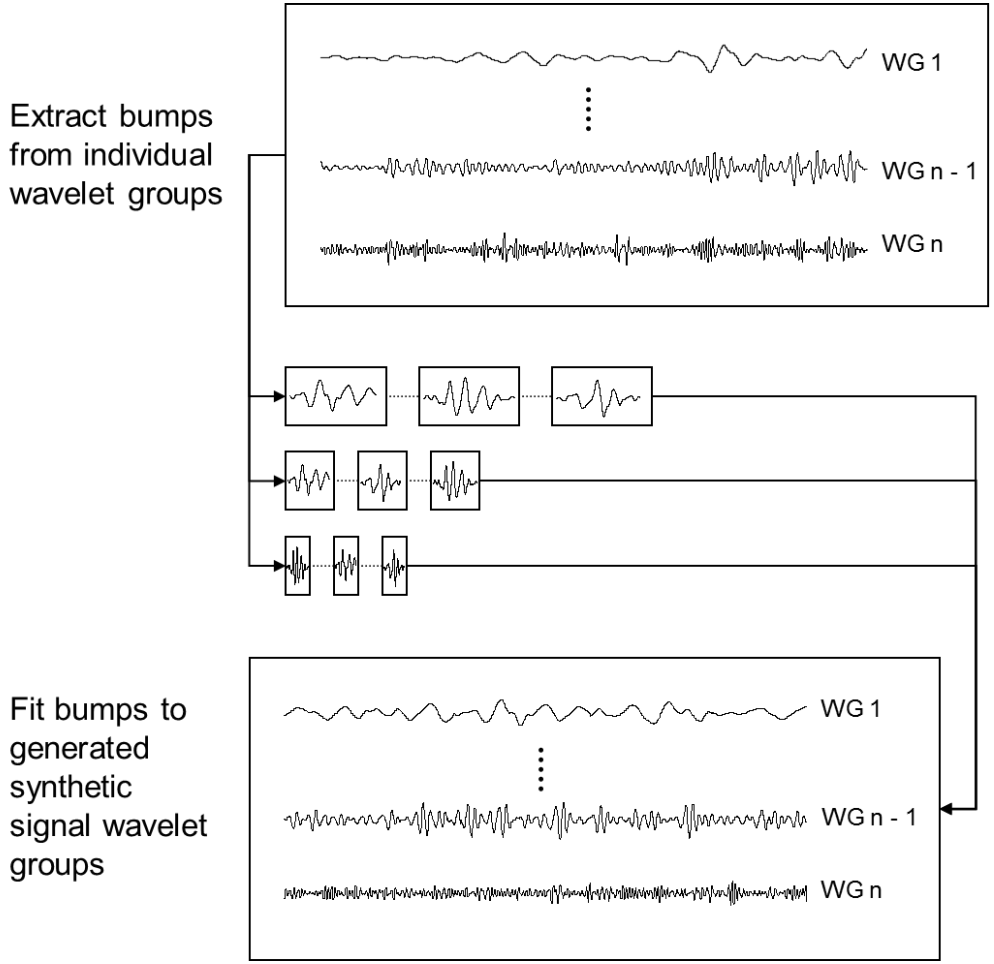
MNMS permits the amplitude scaling, the time dilating and the time repositioning of individual “bump” events.



Mildly Nonstationary Mission Synthesis (MNMS)

MNMS has several different bump reinsertion methods which can be used to redeploy the “bump” events by means of different strategies.

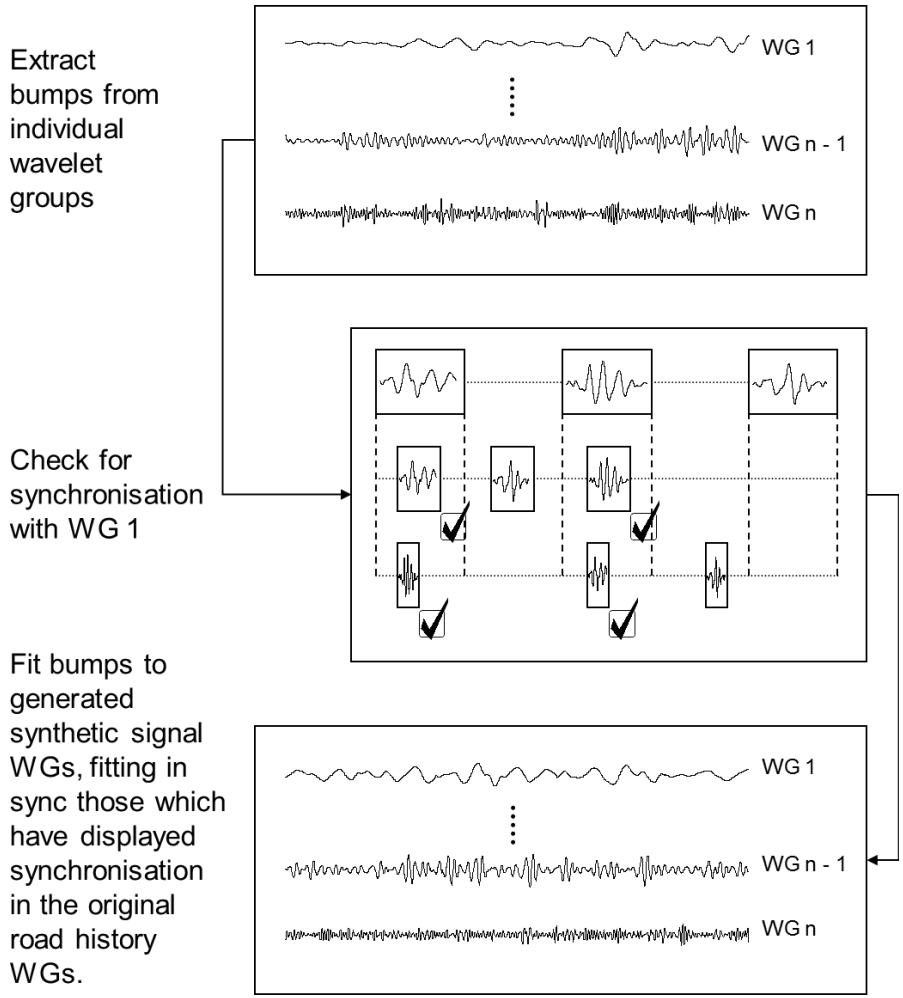
Non-Synchronised Procedure to reinsert “bump” events.



Mildly Nonstationary Mission Synthesis (MNMS)

MNMS has several different bump reinsertion methods which can be used to redeploy the “bump” events by means of different strategies.

Synchronised Procedure to reinsert “bump” events.

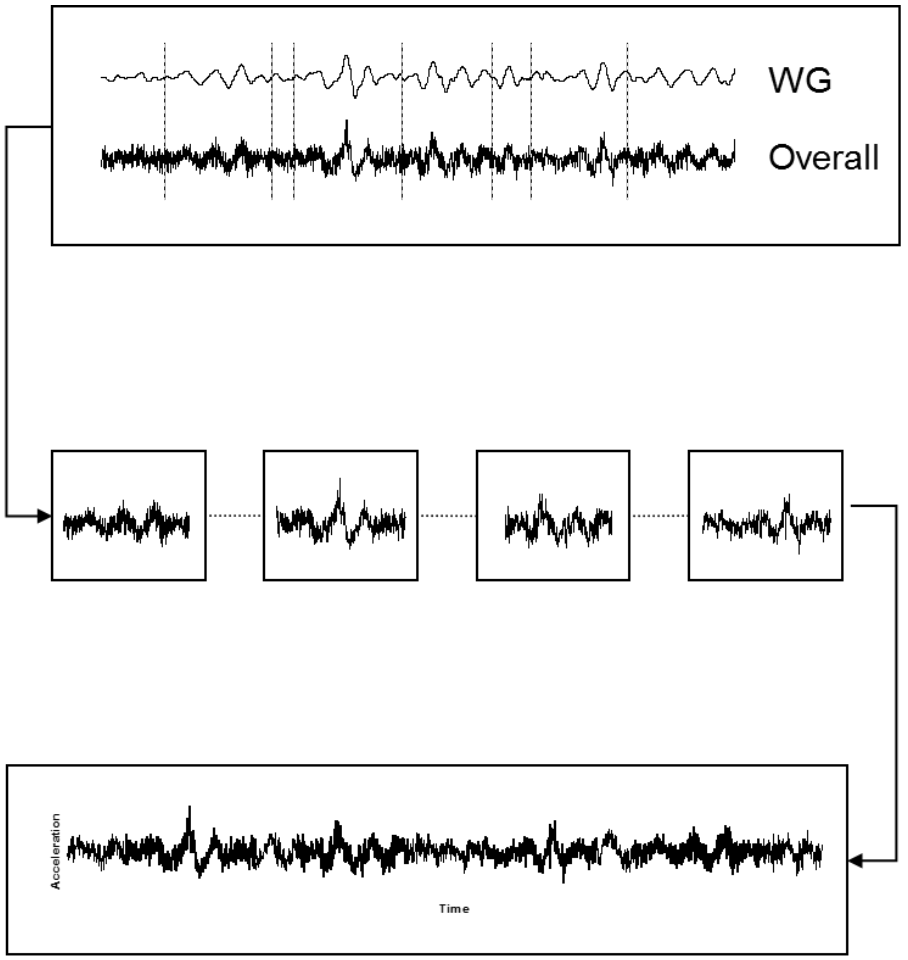


Mildly Nonstationary Mission Synthesis (MNMS)

MNMS has several different bump reinsertion methods which can be used to redeploy the “bump” events by means of different strategies.

Identify-and-Slice Procedure to reinsert “bump” events.

•Determine position of bump event from individual wavelet groups
•Extract bump event from overall time history



Fit bumps to generated synthetic signal

Test Roads

Broken (vehicle speed 40 Km/h)


Broken Concrete (vehicle speed 50 Km/h)


Broken Lane (vehicle speed 40 Km/h)


Cobblestone Road (vehicle speed 30 Km/h)


Concrete Road (vehicle speed 96 Km/h)


Country Lane (vehicle speed 40 Km/h)

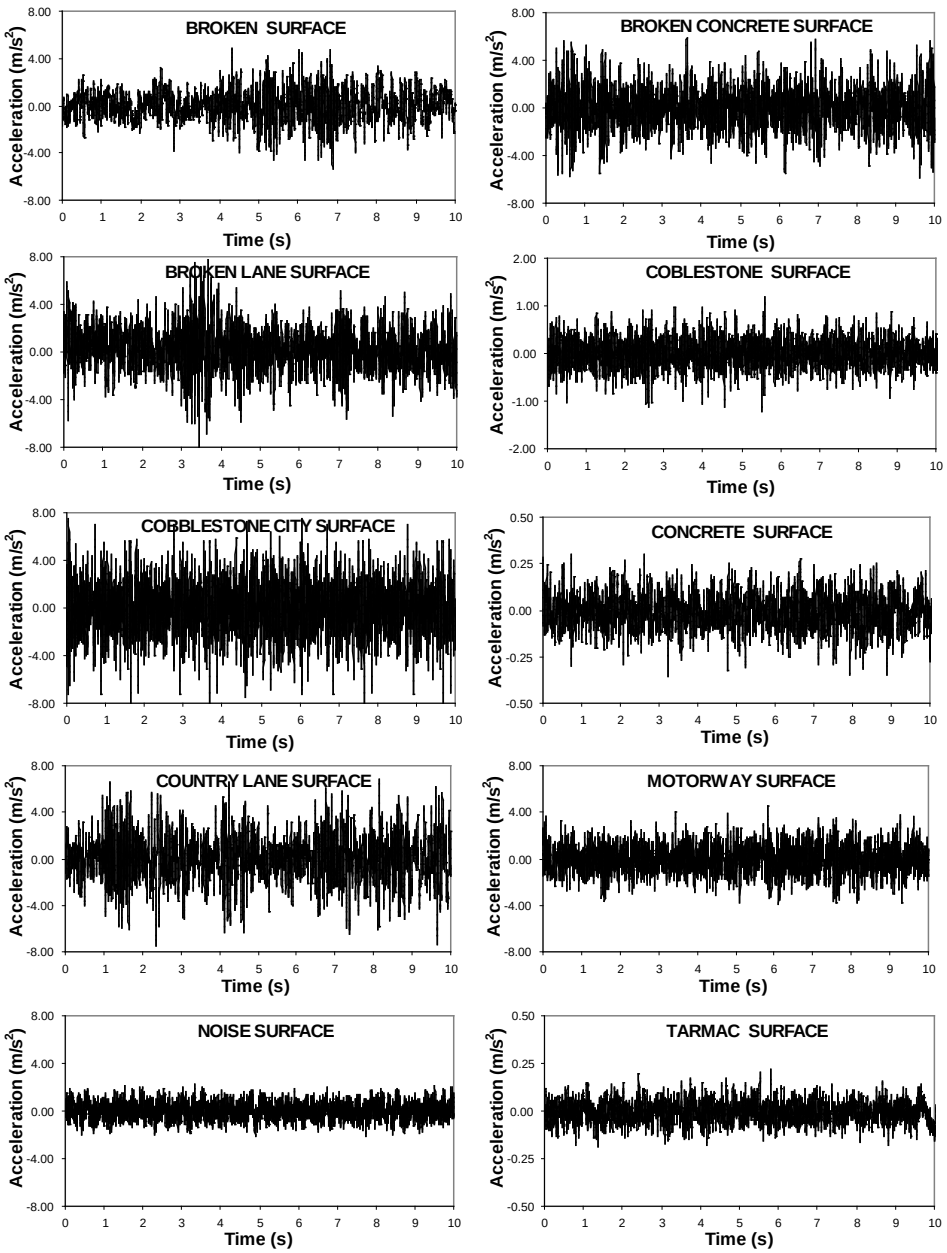

Motorway Road (vehicle speed 110 Km/h)

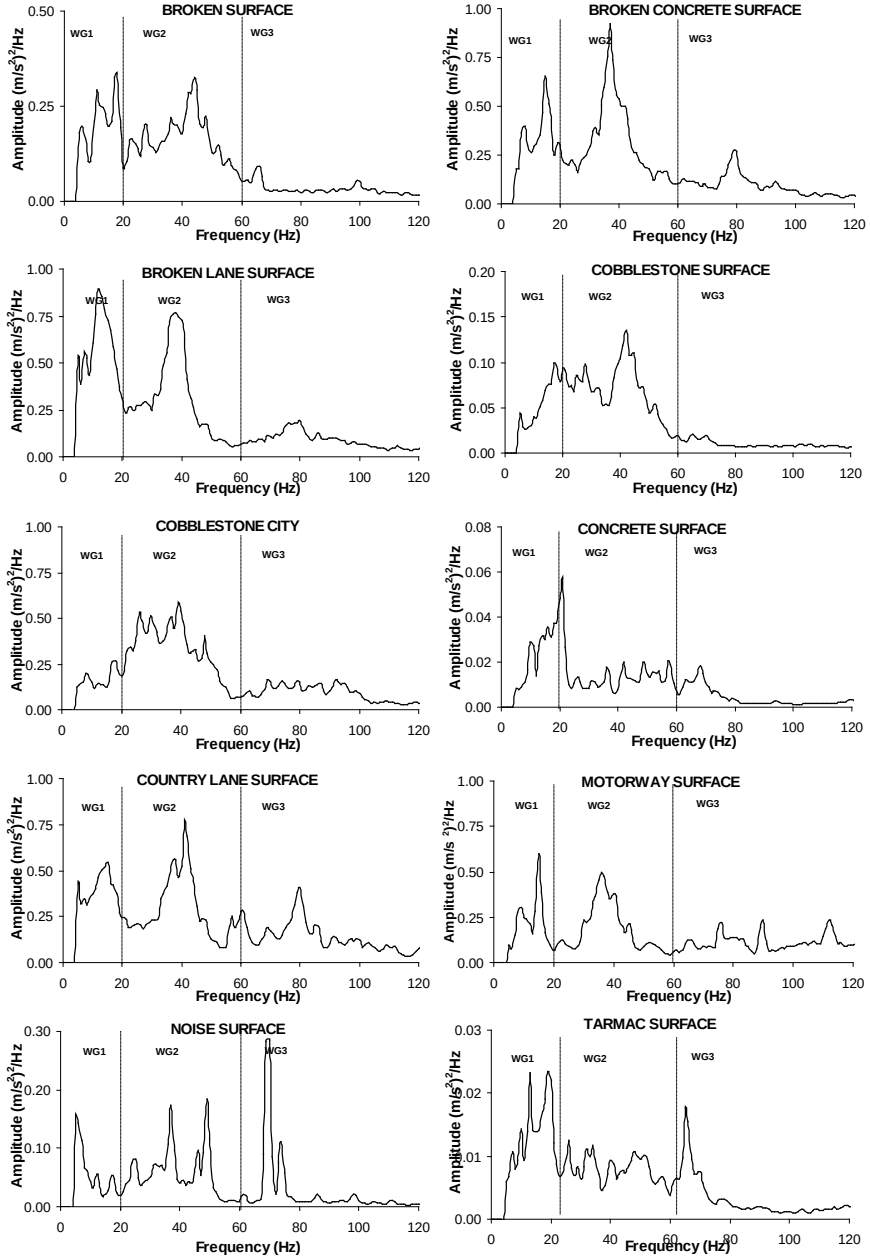

Noise Road (vehicle speed 80 Km/h)


Cobblestone City Road (vehicle speed 40 Km/h)


Tarmac Road (vehicle speed 96 Km/h)


Test Roads

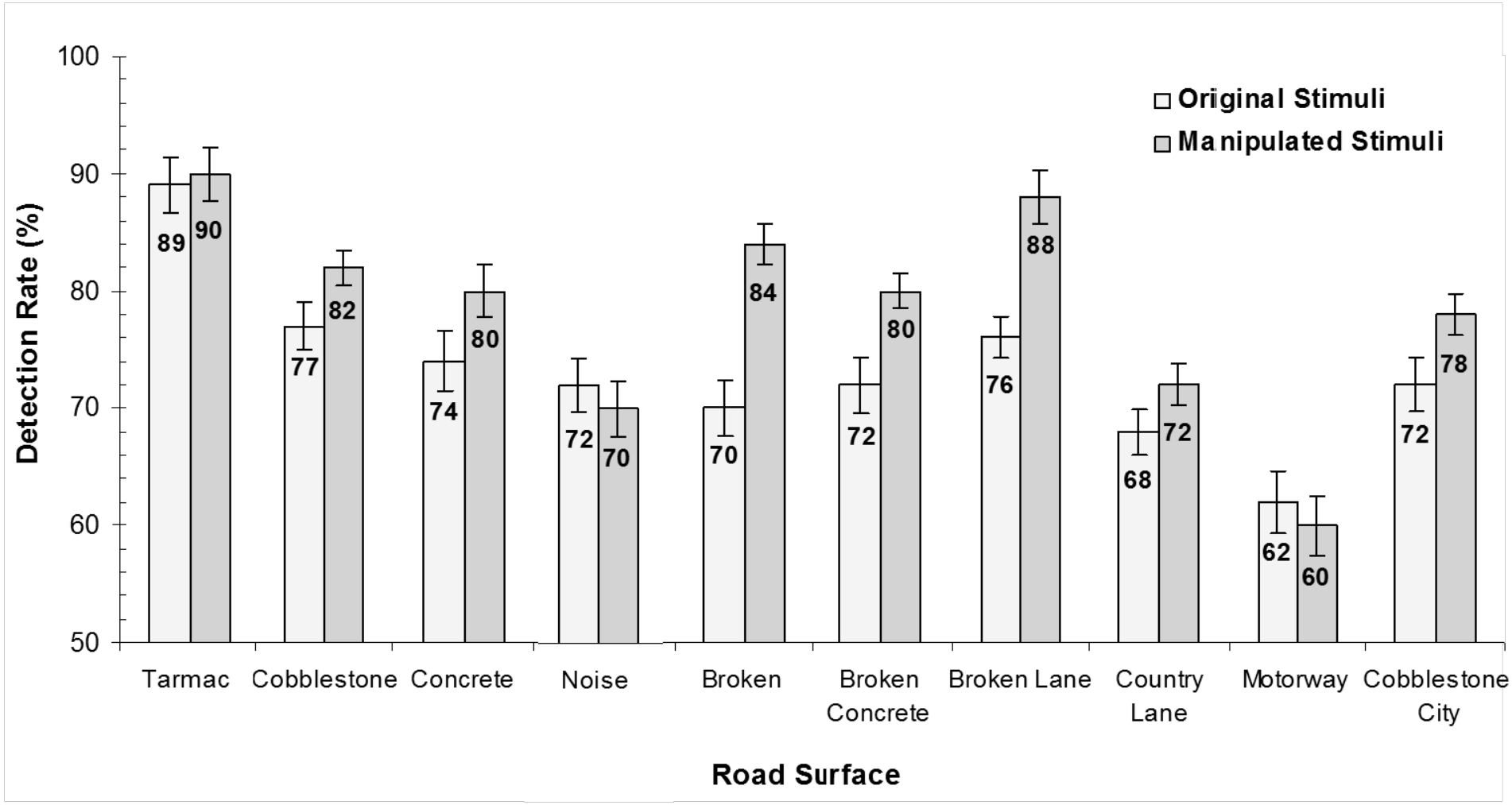

BROKEN SURFACE
BROKEN CONCRETE SURFACE
BROKEN LANE SURFACE
COBLESTONE SURFACE
COBBLESTONE CITY SURFACE
CONCRETE SURFACE
COUNTRY LANE SURFACE
MOTORWAY SURFACE
NOISE SURFACE
TARMAC SURFACE
Acceleration (m/s²)
Time (s)


BROKEN SURFACE
BROKEN CONCRETE SURFACE
BROKEN LANE SURFACE
COBBLESTONE SURFACE
COBBLESTONE CITY
CONCRETE SURFACE
COUNTRY LANE SURFACE
MOTORWAY SURFACE
NOISE SURFACE
TARMAC SURFACE
WG1
WG2
WG3
Amplitude (m/s²)²/Hz
Frequency (Hz)

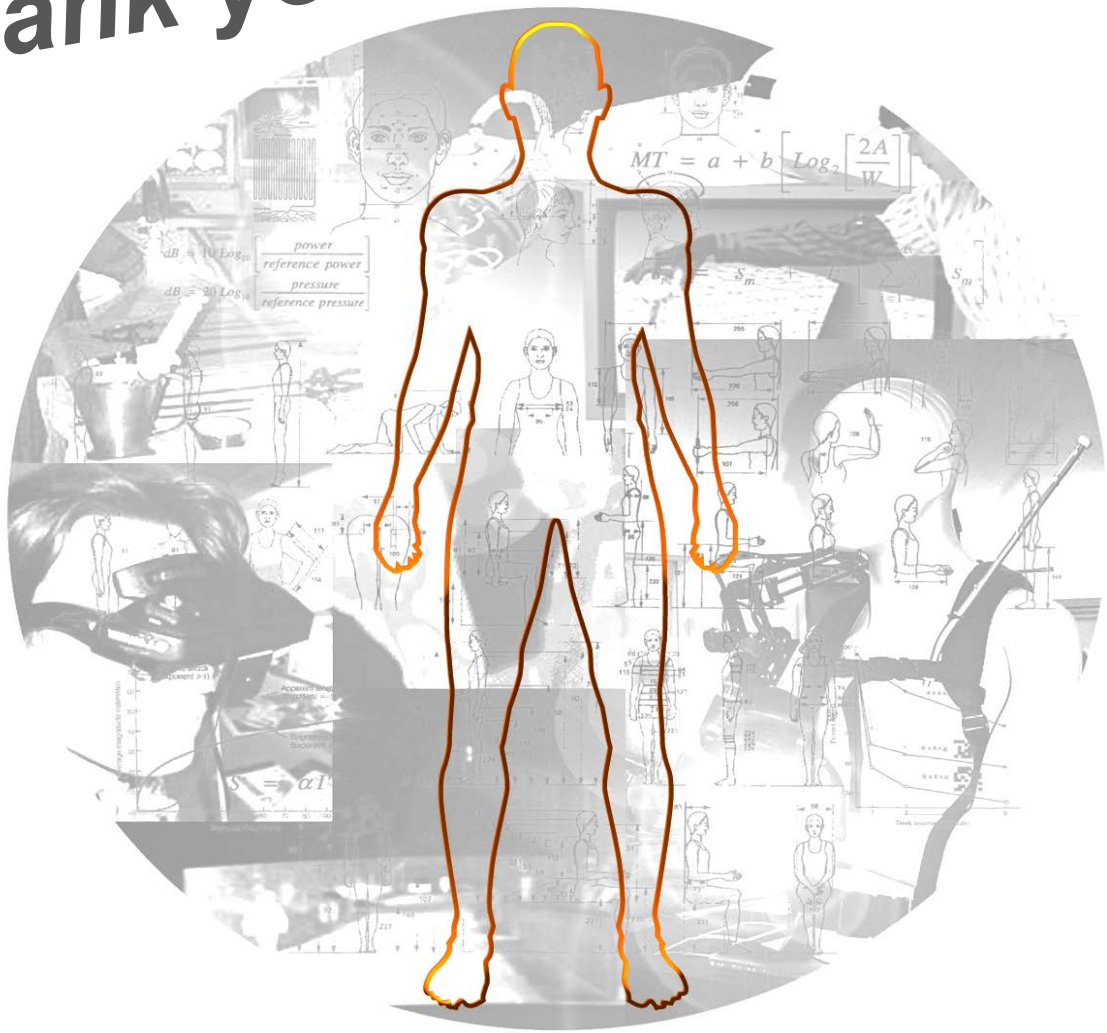
Test Stimuli Defined Using MNMS Algorithm

Specifications	Value	Observations
Frequency Bandwidth	20 to 60 Hz	The “bumps” were extracted from the most important known frequency band.
Threshold Trigger Level (TTL)	2.6	The “bumps” were extracted if they were equal to, or greater than, 2.6 standard deviations.
Compression Ratio (CR)	2.0	The mission signal contained twice as many “bumps” as the original signal.
“Bump” Scaling Factor (SF)	2.0	Each reinserted “bump” was twice the size of the original which was extracted from the original signal.

Effect of Bump Modification on Road Detection



Thank you.


$MT = a + b \left[Log_2 \left[\frac{2A}{W} \right] \right]$
$dB = 10 Log_{10} \frac{power}{reference\ power}$
$dB = 20 Log_{10} \frac{pressure}{reference\ pressure}$