CASE STUDY

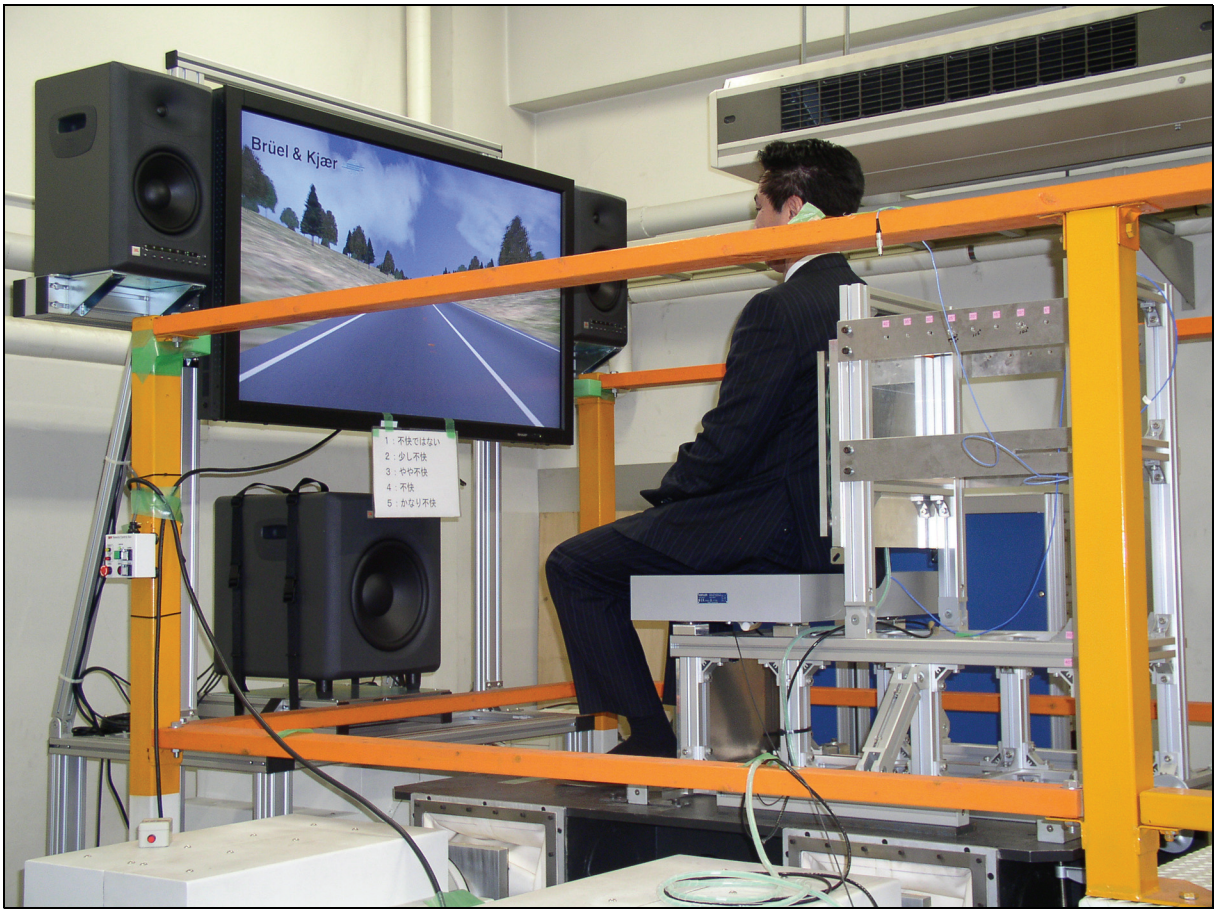
JNIOSH (National Institute of Occupational Safety & Health, Japan) Reproduction of Multi-modal Sensation

Japan

Automotive

NVH Simulator

Traditionally, a single- or multi-degree-of-freedom (DOF) vibrator is used to reproduce vibration for evaluating the effect of whole-body vibration exposure. To add more reality and interactivity, JNIOSH created a system combining sound and visual information generated by a Brüel & Kjær NVH Simulator with the vibration signal generated by a 6-degree-of-freedom vibrator. This new multi-modal simulator plays sound, visuals and vibration simultaneously and the sets of stimuli can be sequenced in arbitrary order. The system is used to perform subjective evaluation with all kinds of psychometric experiments. In addition, it is used to perform, evaluate and correlate measurements for seat vibration comfort in the automotive industry.



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The Company

JNIOSH
National Institute of Occupational Safety and Health, Japan

On 1 April 2006, the National Institute of Industrial Safety (NIIS) and the National Institute of Industrial Health (NIIH) were amalgamated into a single, administrative institute known as the National Institute of Occupational Safety and Health, Japan (JNIOSH). Of all research institutions under the Japanese Ministry of Health, Labour and Welfare, JNIOSH is one of the top institutes in terms of total number of research workers and overall size. JNIOSH is the only comprehensive research institute for occupational safety and health in Japan and actively conducts scientific research to eliminate industrial accidents and diseases, promote workers' health and create a safe and comfortable working environment.

JNIOSH has a strong connection with universities and research organisations worldwide including Loughborough University in the UK with whom they have written joint papers. Working mainly on pure research and collaboration projects funded by customers, JNIOSH undertakes two to three paid projects a year. Among their particular interests are psycho-vibration, comfort evaluation and how vibration affects health and safety issues.

The Human Engineering and Risk Management Research Group is part of the Institute of Industrial Safety. The research activities of this group cover two main areas. One relates to health hazards in work environments, and the other involves occupational accidents. The group is currently conducting health studies relating to dust, harmful gases, noise, sound (including low frequency), vibration and low back-pain; as well as safety studies relating to human errors or organisational errors that result in workplace accidents.

Whole-body Vibration

Human vibration is defined as the effect of mechanical vibration on the human body and it has long been recognised that the effects of direct vibration on the human body can be serious. It can can lead to blurred vision, loss of balance, loss of concentration, etc. In some cases, certain frequencies can permanently damage internal body organs. However, during our normal daily lives we are exposed to vibration of one kind or another, for example, in buses, cars and trains.

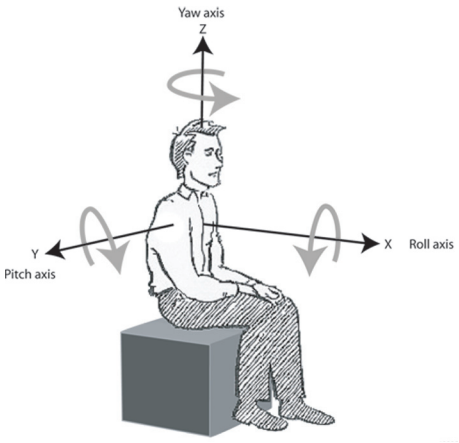
Human vibration can be pleasant or unpleasant and we try to avoid exposing ourselves to unpleasant vibration such as travelling on bumpy roads. There are two main types of human vibration – whole-body vibration and hand-arm vibration. A person driving a vehicle is subjected to whole-body vibration which can disturb the central nervous system. Symptoms of this disturbance usually appear during, or shortly after, exposure in the form of fatigue, insomnia, headache and shakiness. Many people have experienced these nervous symptoms after they have, for example, completed a long car journey. However, the symptoms usually disappear after a period of rest.

Realising the Multi-modal Sensation

To evaluate the effect and perceptible limits of whole-body vibration, some experiments have been carried out with multi-degree-of-freedom (DOF) shakers. However the real environment consists of not only the vibration but also other stimuli, especially visual and audio. Human response to the vibration is almost certainly affected by the visual and audio information, which means it is very important to reproduce the visual and sound stimuli combined with the vibration to investigate the subjective impression of whole-body vibration using the psychometric methods, such as magnitude estimation method, paired comparison, category judgment method and so on.

Multi-modal Simulator

A single- or multi-DOF vibrator has been commonly used to reproduce arbitrary vibration. At JNIOSH, the 6-DOF vibrator system has been used to examine the effect of whole-body vibration. This system has seven vibrators to create 6-DOF (X, Y, Z, Roll, Pitch, and Yaw) vibration.



Rotation around the front-to-back axis is called roll. Rotation around the side-to-side axis is called pitch. Rotation around the vertical axis is called yaw

Dr. Setsuo Maeda, Dr. Eng., Dr. Med. Sci., Director, Human Engineering and Risk Management Research Group, JNIOSH, explains their needs, "To accurately evaluate the relationship between vibration and subject response requires that the vibration input must be as accurate as possible. This necessitates the combination of vibration plus sound and visual stimuli. And so our need for the multi-modal simulator was created".

A 6-DOF Vibrator System

The NVH (Noise, Vibration and Harshness) Desktop Simulator was originally developed to add interactivity and more context to the evaluation of vehicle sounds by adding the visual (and optionally the vibration) stimuli. A number of car manufacturers started introducing the simulator to design the sound of vehicles under the virtual driving environment.

The NVH Simulator, provided by Brüel & Kjær and NoViSim Ltd., was customised to suit JNIOSH's particular requirements. With its different virtual driving scenarios on roads including a variety of surfaces and bumps, it was integrated to the vibrator system enabling multi-modal experimentation on whole-body vibration.

Dr. Setsuo Maeda, Dr. Eng., Dr. Med. Sci., Director, Human Engineering and Risk Management Research Group, JNIOSH

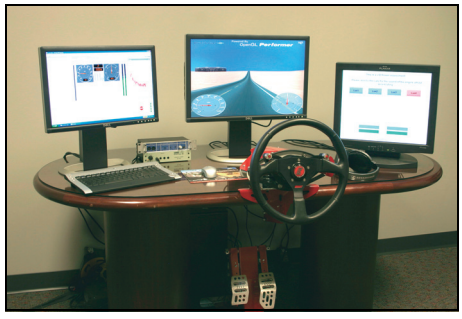
Dr. Maeda explains, "The automotive industry strongly focuses on comfort and the multi-modal system combines vibration with visual and aural input. This enables us to experiment and conduct research into the relationship between vibration and subjective responses. The addition of the NVH Simulator adds more context interactivity and reality". However, the driving is passive and not active – there is no steering wheel and no pedals. The speed is fixed but can be adjusted by the operator. The data is canned data provided by NoViSim Ltd. The input to the shaker is based on real vibration and there are many different programs and vibration levels.

These two systems were integrated to replay the vibration, sound and visual stimuli simultaneously. The start timing is controlled by NVH Simulator with trigger signal with a definable delay.

Stimuli

The multi-modal system requires three kinds of stimuli:

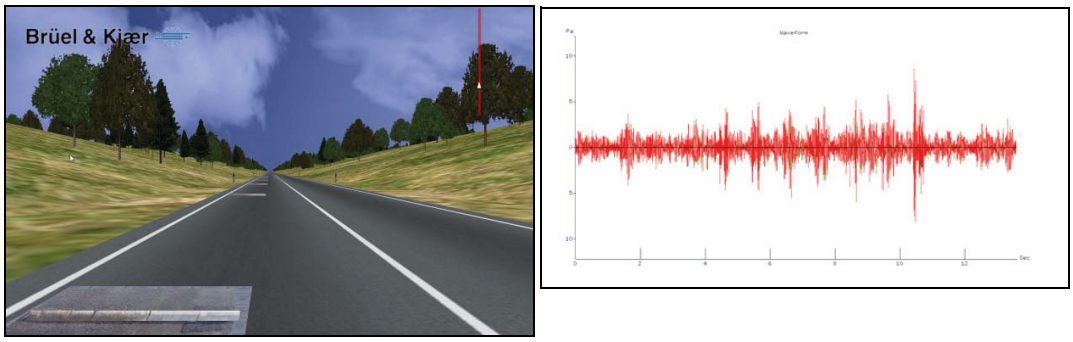
- Vibration – Acceleration signals measured at driver's seat in three directions
- Sound – Sound pressure signals measured at both driver's ear positions with binaural recording microphone
- Visual – Computer graphics created semi-automatically from vehicle performance data, such as vehicle speed and engine speed. Adding trees or hills is user-definable



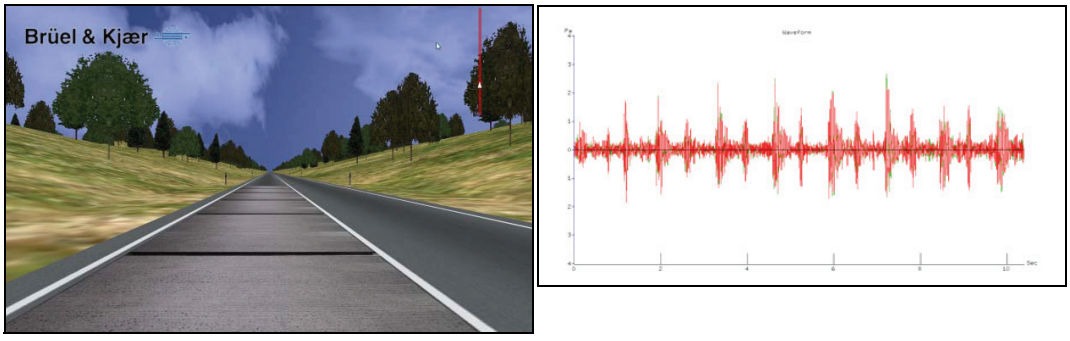
The standard NVH Desktop Simulator

The series of stimuli were prepared from measurements made on passenger cars. The cars drove on roads with different kinds of bumps at constant speeds.

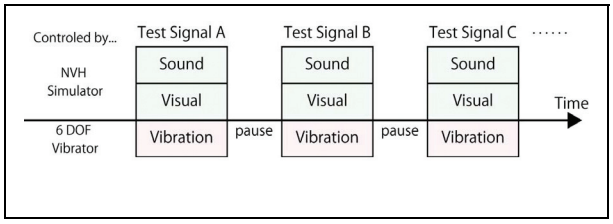
An example of stimuli with large impacts driving at 60 km/h: Visual (left) and sound wave form (right)



An example of stimuli with concrete joints driving at 16 km/h: Visual (left) and sound wave form (right)



The sequence of the stimuli in the time domain



As well as the visual scenario, the sound and vibration are played and synchronised with the bumps on the screen. These sets of stimuli can be linked together in an arbitrary order with changeable pauses between them for voting. The stimuli can be combined in different ways for presentation. This means that it is possible to make a test with and without visuals to investigate the effect of visible information on the perception of vibration. Sound and visual signals are controlled by the NVH Simulator and the vibration signal is controlled by the 6-DOF vibrator. These three signals are played simultaneously. In addition, these stimuli can be created with arbitrary length from any measured data in a vehicle.

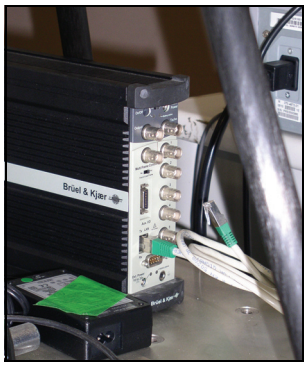
Seminar Introducing the Multi-modal Simulator

Kazuma Ishimatsu Ph.D., Researcher for the Human Engineering and Risk Management Research Group, JNIOSH

In December, 2009, a seminar at JNIOSH was attended by more than 40 representatives ranging from Japanese auto manufacturers and suppliers, railway companies and locomotive manufacturers, and many other interested research and disaster prevention institutions. At the seminar, the multi-modal simulator, which will be utilised to perform several kinds of psychometric experiments, such as magnitude estimation method, method of paired comparison, category judgment method, etc., was presented.

Kazuma Ishimatsu Ph.D. is a Researcher for the Human Engineering and Risk Management Research Group, JNIOSH. He says, “At JNIOSH we were very pleased that so many people attended the seminar. It is very clear that there is a high level of interest in psychovibration and I am excited by the new fields of research which are now open to us with the multi-modal simulator”.

Kazuma Ishimatsu says, “Our first use of Brüel & Kjær products dates back to 2000. We especially like their quality, reliability and we have no doubts that the data is always totally accurate”. He continues, “The service and support we receive from Brüel & Kjær’s Japanese office is a major benefit”.



Brüel & Kjær products at JNIOSH include:

- Head and Torso Simulator Type 4128
- 4 × PULSE systems for general sound and vibration measurements such as 1/3-octave, CPB and FFT:
  - 2 × 2-channel Type 3560-B frames
  - 1 × 4-channel Type 3560-C frame
  - 1 × 24-channel Type 3560-D frame
- A large quantity of microphones and accelerometers

Dr. Maeda adds, “I was particularly pleased that so many representatives from automotive companies attended the seminar. In the past, we have worked on joint projects with many of the major Japanese manufacturers, and as a result of the seminar we will be continuing our research into automotive vibration comfort”.

With grateful thanks to JNIOSH and NoViSim Ltd. for their valuable assistance in preparing this case study.

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