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Masking of thresholds for the perception of fore-and-aft vibration of seat backrests

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ABSTRACT

The detection of a vibration may be reduced by the presence of another vibration: a phenomenon known as 'masking'. This study investigated how the detection of one frequency of vibration is influenced by vibration at another frequency. With nine subjects, thresholds for detecting fore-and-aft backrest vibration were determined (for 4, 8, 16, and 31.5-Hz sinusoidal vibration) in the presence of a masker vibration (4-Hz random vibration, 1/3-octave bandwidth at six intensities). The masker vibration increased thresholds for perceiving vibration at each frequency by an amount that reduced with increasing difference between the frequency of the sinusoidal vibration and the frequency of the masker vibration. The 4-Hz random vibration almost completely masked 4-Hz sinusoidal vibration, partially masked 8- and 16-Hz vibration, and only slightly masked 31.5-Hz vibration. The findings might be explained by the involvement of different sensory systems and different body locations in the detection of different frequencies of vibration.

1. Introduction

Fore-and-aft vibration of a backrest is one of the principal sources of discomfort for drivers and passengers in vehicles. For seated people supported by an upright backrest, equivalent comfort contours for vibration applied to the back show greater sensitivity to fore-and-aft vibration than vibration in either of the other two directions (i.e., vertical or lateral) over the frequency range 2.5–63 Hz (Parsons et al., 1982). Over the range from 2 to 16 Hz, thresholds for perceiving fore-and-aft vibration at the back are similar to, or lower than, thresholds for perceiving vibration at the feet or the seat (Gallais et al., 2015). Since backrests amplify some frequencies of vibration (Jalil and Griffin, 2007; Basri and Griffin, 2014), the perception of fore-and-aft vibration can be dominated by vibration of the back.

Sensitivity to fore-and-aft vibration of the back depends on the frequency of vibration and contact conditions with the backrest. A frequency weighting for evaluating the severity of fore-and-aft backrest vibration (weighting W_c in BS 6841:1987 and ISO 2631-1:1997) was based on experimental studies that determined the acceleration of a backrest required at various frequencies to cause discomfort equivalent to that caused by 10-Hz vertical vibration of a seat at a magnitude of 0.8 ms^{-2} r.m.s. The experiment produced an equivalent comfort contour showing greatest sensitivity to acceleration at frequencies between 2.5 and 8 Hz. At higher frequencies, sensitivity to acceleration reduced in proportion to the frequency of vibration, corresponding to similar discomfort with similar vibration velocity (Parsons et al., 1982). Similar equivalent comfort contours have been reported from other studies with fore-and-aft vibration of a full upright backrest (Kato and Hanai, 1998; Morioka and Griffin, 2010; Basri and Griffin, 2011) but with variations dependent on the location of contact with the back (Morioka and Griffin, 2010) and the inclination of the backrest (Kato and Hanai, 1998; Basri and Griffin, 2011). Unlike equivalent comfort contours for vertical seat vibration, it seems that equivalent comfort contours for the back are not highly dependent on the magnitude of vibration (Morioka and Griffin, 2010; Basri and Griffin, 2011).

The detection of one type of vehicle oscillation may be expected to be influenced by the presence of other vibrations (e.g., background vibration): a phenomenon known as 'masking' (i.e., the detection of one stimulus is 'masked' by the excitation associated with another stimulus). With vibrotactile stimuli applied to a small area of the thenar eminence of the hand, masking occurs when the masker stimulus and the test stimulus stimulate the same tactile channel (e.g., Gescheider et al., 1982) and similar masking has been

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observed in the perception of hand-transmitted vibration (Morioka and Griffin, 2005). There is no known study of the influence of masking on the perception of whole-body vibration. It seems reasonable to anticipate that greater understanding of masking will improve the prediction of the sensations caused by vibration in vehicles.

A 'masked threshold' is the threshold for the perception of a stimulus determined in the presence of another stimulus. It may be expected that masking will be greatest when the two stimuli are perceived by the same mechanism (e.g., by exciting the same sensory system at the same location in the body). This is sometimes called 'energetic masking' (EM), as opposed to 'informational masking' (IM) where the detection of one stimulus is impeded by distraction from another stimulus (Durlach et al., 2003). When two vibration stimuli have different frequencies, they may be perceived at different body locations even if they enter the body at the same location (because different frequencies excite different motions in the body). For each of the three translational axes of vibration of a seat with no backrest, the location of discomfort in the body is more dependent on the frequency of vibration than the magnitude of the vibration (Whitham and Griffin, 1978). With fore-and-aft vibration of the back in the frequency range 2.5–25 Hz, discomfort is mostly localised in the upper or lower back at all frequencies, although with increased perception at the head, neck, or shoulders at 20 and 25 Hz (Basri and Griffin, 2011). In part, this reflects the complex biodynamic responses of the body to vibration applied at the back (Jalil and Griffin, 2008).

This laboratory study was designed to investigate masked thresholds for sinusoidal fore-and-aft vibration of a backrest. It was hypothesised that thresholds for detecting a sinusoidal vibration stimulus would increase with increasing intensity of a masker stimulus (a random background vibration) but that the threshold shift would depend on the frequency of the sinusoidal stimulus, reflecting the detection of the different frequencies of vibration either by different sensory systems (e.g. somatosensory, vestibular, visual, etc.) or at different body locations. The findings of this study have application to predicting whether a particular vibration of a vehicle will be detected by drivers or passengers when there are other vibrations present.

2. Method

2.1. Subjects

Nine males aged between 21 and 29 years, with a mean age of 24.6 years (standard deviation, SD = 2.7), a mean stature of 174.7 cm (SD = 10.8) and a mean weight of 68.8 kg (SD = 14.1) participated in the experiment. All subjects were students or office workers with no history of occupational exposure to vibration.

The experiment was approved by the Human Experimentation Safety and Ethics Committee of the Institute of Sound and Vibration Research at the University of Southampton. Informed consent to participate in the experiment was given by all subjects.

2.2. Apparatus

Fore-and-aft backrest vibration was produced by a rigid flat vertical wooden plate (640 × 680 mm) secured to a trunnion-mounted Derritron VP 85 vibrator. Subjects sat on a stationary rigid seat and supported their feet on a stationary rigid footrest (Fig. 1). The height of the footrest was adjustable so that the upper surfaces of the upper legs of subjects were horizontal.

A piezoelectric accelerometer (DJ Birchall, type A/20T) was attached to the centre of the rear surface of the wooden plate and the signal amplified by a charge amplifier (Brüel and Kjær, type 2635). Vibration signals were generated and acquired using *HVLab* Data Acquisition and Analysis Software (version 3.81) to a personal computer via anti-aliasing filters (TechFilter) and analogue-to-digital and digital-to-analogue converters (PCL-818). The signals were generated at 500 samples per second and passed through 45-Hz low-pass filters. The stimulus parameters and the psychophysical measurement procedures were controlled by the computer. The background vibration, mostly electrical noise at 50 Hz, was less than 0.005 ms^{-2} r.m.s., and was not perceptible via the backrest. With all stimuli, the cross-axis accelerations were less than 5% of the fore-and-aft acceleration.

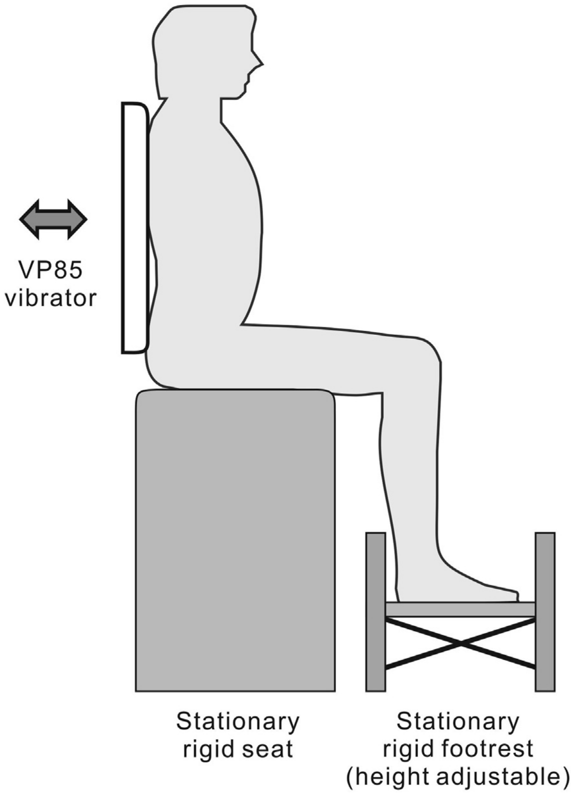

Fig. 1. Posture adopted by the subjects sitting on a stationary rigid seat with a stationary footrest and exposed to fore-and-aft vibration at the back. The subjects maintained their sitting postures with their hands on their laps, looking straight ahead.

During the experiment, the subjects were exposed to acoustic white noise at 65 dB(A) via a pair of headphones so that they all experienced the same noise in all four sessions, so that they could not hear the vibration, and so that they could concentrate on the vibration without being distracted by sounds in the laboratory. The acoustic noise generated by the vibration stimuli was inaudible even without the masking noise.

2.3. Stimuli

Sinusoidal vibratory stimuli, 2 s in duration, with rise and fall times of 0.5 s were created with cosine-tapered ends. Four test stimuli, with frequencies at 4, 8, 16, and 31.5 Hz, were prepared. A Gaussian random masking stimulus, 7 s in duration, was created with a 1/3-octave bandwidth centred at 4 Hz (filter pass-band 3.55–4.47 Hz). The masking stimulus, which varied in intensity according to the perception threshold for the masker measured for each subject at the beginning of each session, was presented at five levels from threshold up to 24 dB SL in 6 dB steps (i.e., at 0, 6, 12, 18, and 24 dB above the threshold level of the subject). The stimulus