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Masking effects in vertical whole body vibrations

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The existence of masking effects for vertical vibrations of seated subjects was investigated. In the first experiment, detection thresholds of sinusoids at six different frequencies (between 30 and 80 Hz) were estimated using a 3-AFC with a three-down one-up rule. Then, thresholds were estimated in the presence of a vibratory masking stimulus: a band pass noise (10 to 20 Hz) at three different levels (between 0.1 and 0.315 m/s^2). The presence of this band-pass noise increased the threshold of all studies frequencies. At detection, the overall level of the signal (masker noise plus sinusoid) was greater than the level of the masker noise alone by a value close to the just noticeable differences in level for this noise. Results suggested that the detection was related to a global energy level discrimination process. Finally, some indicators explaining this phenomenon are presented.

1 Introduction

During daily activities, humans are exposed to multiple sources of vibratory stimuli. In very few cases it is a single stimulus; in most cases it is the result of the contribution of different signals. In the literature, some studies [1-9] analyze the human response to a single sinusoidal vibration stimulus, in the vertical direction, and the effect of some variables (frequency, duration, body support elements, body posture, etc.). In [5], the perception threshold of a vertical sinusoidal signal in the presence of a second sinusoidal stimulus to a lower frequency is presented; results suggest that the subjects can more easily detect the test signal when its frequency is close to the base signal. In this case, there are some indications that the presence of a second signal facilitates the detection of test stimulus, but the opposite possibility, i.e. the masking effect has not been explored.

This study investigates the existence of masking effect for vertical vibration of seated subjects; the signal test is a sinusoidal vibratory stimulus and the mask is a band-pass noise vibratory stimulus. Some indicators that contribute to understand the mechanism of detection are presented.

2 Experimental Method

All experiments were conducted using a test bench located in the Laboratoire Vibrations Acoustique (LVA-INSA de Lyon), France.

A spring supported platform on which a seat is fixed, is connected to an electrodynamic shaker (type LDS V650). This transmits the vibration in the vertical direction to the seat of the bench; a data acquisition system (type NVGate OROS®) and a piezoelectric accelerometer (PCB Piezotronics, Model 333B32) which is placed at the bottom of the seat are used to analyze and record the movement. Using special software developed for this investigation, a vibration signal is generated. Then, the computer transmits this signal to an amplifier (type PA 1000L) through a data acquisition card (type Plug.n.DAQ, Roga).

A flat circular base wood seat (0.305 m diameter and 0.02 m thick), is the surface through which the vibration is transmitted.

The seat does not have any support for the back, head or arms.

The subject is asked to sit down in an upright position as see in Figure 1. His feet are placed on a fixed platform. Some experiments were conducted at the same positions (no backrest and stationary footrest) [7]. The obtained thresholds were not similar than those obtained with not stationary footrest.

In all experiments, the stimuli are vibratory signals in vertical direction.

Two types of stimuli have been used: the masking and the test stimulus.

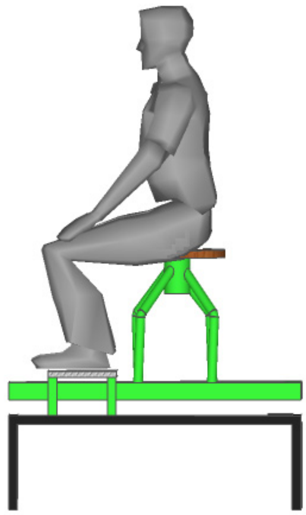

Figure 1: Subject position during tests.

The masker is a narrowband noise (10-20 Hz) at three different magnitude levels (100, 105 and 110 dB).

When both the masker and sinusoidal signals are simultaneously present, the risk of detection due to the values at hollow positions is high. In order to avoid this risk, the amplitude of signal test was multiplied by the contour of the mask stimulus. Therefore, the test stimulus is a sinusoidal modulated amplitude signal.

The test frequency is between 30 to 80 Hz. Within this frequency range the movement influences, other than vertical direction, can be despised.

To examine the masking effect, the difference between absolute and masked thresholds is required; hence, both thresholds have been estimated.

Due to the variation in the overall level energy arising from the simultaneous presentation of two stimuli (test and mask stimuli), the just noticeable difference (JND) of the masking signal has been estimated at three different magnitudes levels (100, 105 and 110 dB).

All tests have been carried out using three alternative forced choice (3AFC) methods in conjunction with a three-down one-up rules algorithm. In all studies, the test and mask signal duration were 2.0 seconds (including 50 ms fade at the ends).

The task of the subjects was to identify which interval was different from the two others. No feedback was provided to the subject. The order of test stimuli presentations was randomized.

The procedure for determining the thresholds and the JND was terminated after 10 reversals: a point where the stimulus magnitude reversed direction at either a peak or a trough. The thresholds and JND were calculated from the mean of the last four reversals, omitting the first two. The final value is the median of all participants.

All parameters estimated in this study are expressed in terms of the acceleration: dB and m/s^2 which is the recommended method for the quantification of human exposure to vibration in the relevant international standards [1].

Nine (3 female, 6 male) and twelve (3 female, 9 male) healthy subjects participated in thresholds and JND tests respectively.

3 Results and Discussion

3.1 The absolute threshold

The Individual, median and inter-quartile range (25-75th percentiles) of the absolute threshold estimations are presented in Figure 2.

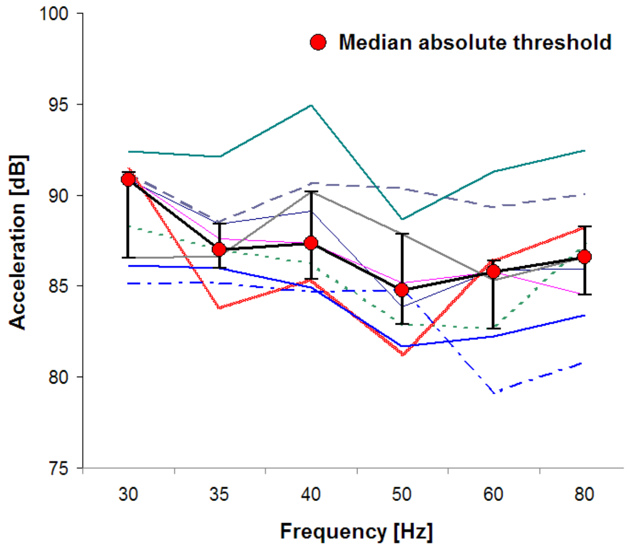

Figure 2: The Individual, median and inter-quartile range (25-75th percentiles) of the absolute threshold.

Some differences between the values of individual thresholds across the frequencies range have been found.

The median and the inter-quartile range (25-75th percentiles) of absolute threshold are shown in Figure 3; the results of other studies are displayed for comparison.

In general, the thresholds values are similar to those shown in Figure 3 in spite of the differences within the tests signals. An explicit comparison between the data is not possible because the differences conditions (psychophysical procedures, system for generating motion, stimuli, etc.) may influence the final absolute threshold value [10-11].

It can be observed that the frequency effect on the absolute threshold is not the same for all range. From the statistical analysis, with a significance level of 0.05 (for all the cases) a significant difference between 30 Hz and all other frequencies (except to 40 Hz) was detected. However, between 35 Hz and all other frequencies, the sensitivity change is very low (no significant differences), except for 50 Hz. The most important sensitivity change is between 30 and 50 Hz.

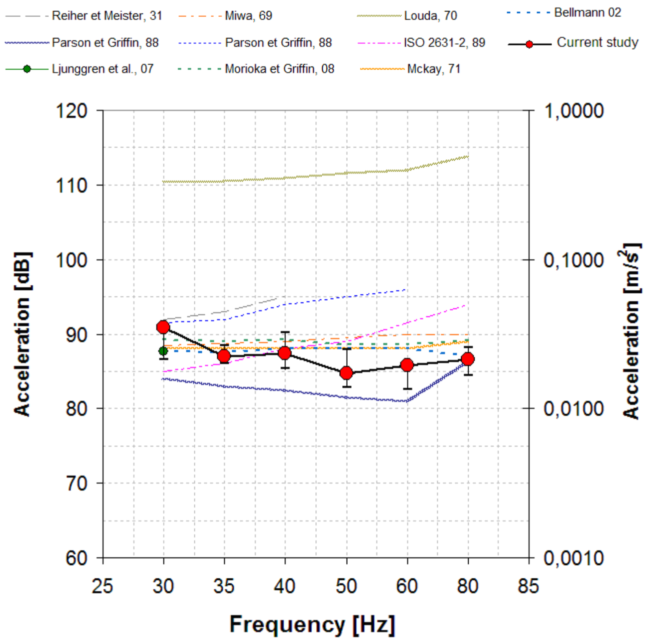

Figure 3: The median and the inter-quartile range (25-75th percentiles) of absolute threshold of whole-body vertical vibration, some data are based on [2] and [3].

3.2 The masked threshold

The masked threshold has been estimated by using a test stimulus at the frequencies 30, 35, 40, 50, 60 and 80 Hz; the mask signal was only at 110 dB level amplitude. The individual, median and inter-quartile range (25-75th percentiles) of masked threshold as frequency function are shown in Figure 4.

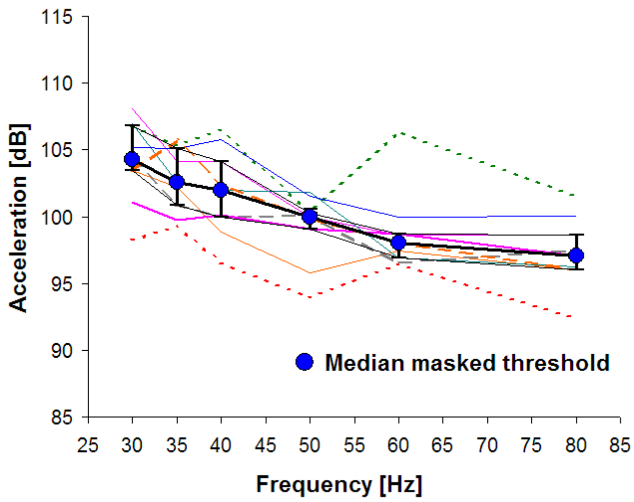

Figure 4: The Individual, median and inter-quartile range (25-75th percentiles) of masked thresholds.

Sensitivity differences between individual values were observed. Nevertheless, some similarity with respect to the trend of the masked threshold has been found.

In Figure 5, are presented the median and inter-quartile range (25-75th percentiles) of masked threshold estimated; to facilitate the analysis of results, the absolute threshold of perception is also displayed.

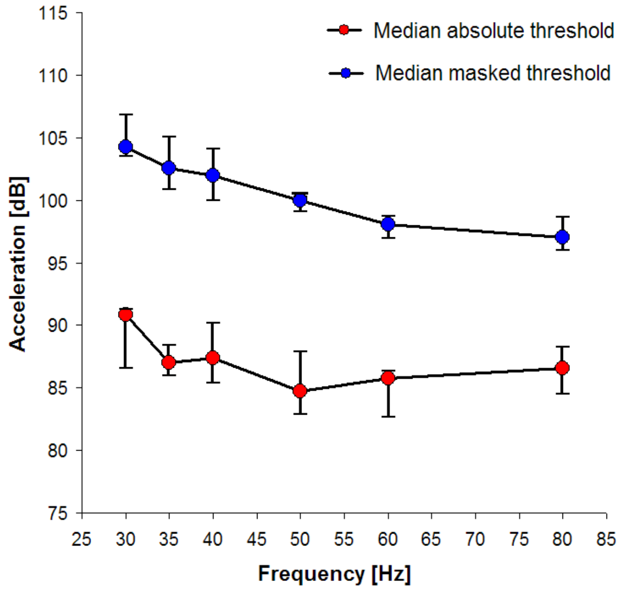

Figure 5: The median and inter-quartile range (25-75th percentiles) of absolute and masked threshold.

Significant differences in all frequency range have been found between the absolute threshold and the masked threshold (0.05 significance level, Wilcoxon, $p < 0.05$).

The masked threshold exhibits a tendency to decrease as function of test signal frequency. Significant differences at most of frequencies of masked threshold were found (0.05 significance level, Wilcoxon, $p < 0.05$).

In general the masked threshold shown values considerably higher than those corresponding to the absolute threshold at the same frequency; the results suggest that detection of the test signal is affected by the presence of the mask signal at 110 dB of amplitude level.

Using the test signal only at 35 Hz and the mask signal at 100, 105 and 110 dB magnitude levels, the masked threshold has been estimated.

The masked threshold as a function of the mask signal level, is shown in Figure 6, the absolute threshold is shown too for a better analysis.

The masked threshold values are significantly higher than the absolute threshold values (more than 10 dB) at all mask signal levels.

According to the results, it appears likely that the mask signal level affects the detection of the signal test at 35 Hz; the tendency suggests that the effect of mask signal level is more important as it rises.

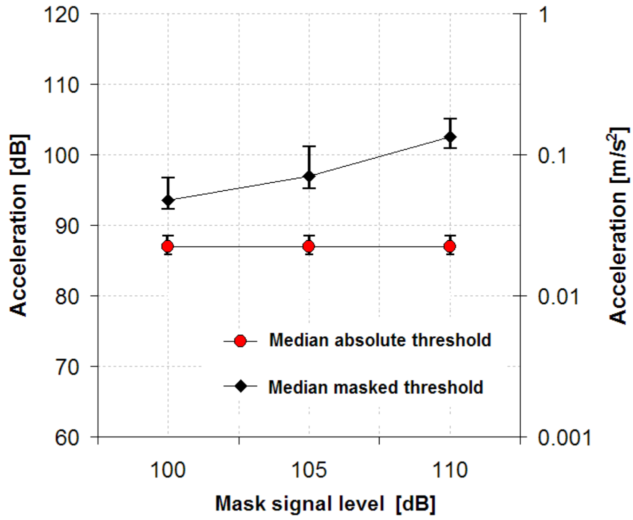

Figure 6: Median and inter-quartile range (25-75th percentiles) of masked threshold.

3.3 The just noticeable difference (JND)

The absolute values, median and inter-quartile range (25-75th percentiles) of JND in level estimated in the present investigation, are shown in the first line (*) Table 1.

The JND in level reported by [3], [12], [13], and [14] are between 0.52 and 1.5 dB, however those values were obtained from sinusoidal signals and they are considered only for reference purposes but not for direct comparison.

Table 1: Just noticeable difference in level (absolute values) (*) [dB], Minimum level energy expected (**) [dB], Level energy reported (***) [dB].

	Mask signal level		
[dB]	100	105	110
(*)	1.9 (1.4-2.5)	2.4 (1.9-3.2)	1.7(1.4-1.8)
(**)	101.55	106.91	111.34
(***)	101.18	105.92	110.80

The minimum energy level required to detect a change in the mask signal (mask signal + JND), is shown in the second line (**) Table 1: those are the values at which should have been detected the energy change of the mask signal.

The energy levels, at which the detection took place (mask signal + test signal), are shown in third line (***) Table 1: when comparing the expected energy level for detection with the value at which the detection in fact occurred, we observed some differences.

A similar analysis was conducted for each of the subjects who participated to both experiences. In most cases (16 over 18), when the signal was detected the difference between the level of the combination (mask signal + JND) and the level of the masker alone, was lower than the JND's mentioned in Table 1. This can indicate that a frequency discrimination process occurred. Thus, the energy level required for this frequency discrimination is below than the level required to intensity shift discrimination.

4 Conclusions

In the present work, the frequency dependence of the absolute threshold is similar to the results presented in other studies; however, explicit comparison to this database is not possible. Disagreement can be attributed to differences in body posture and body support elements [4] and the use of different psychophysical methods [15]. Since the whole body vibration can be detected by vision, hearing and vestibular senses [2], other aspects such as the duration of the stimulus, different systems for vibratory movement generation, groups of subjects and the test environment, could also influence the final thresholds values.

The stimulus detection in the presence of the masking signal has been prevented. Therefore, it is certainly clear that the masking phenomenon occurred. The masked thresholds values were considerably higher than those absolute thresholds.

The threshold decreases as a function of test frequency and the mask effect is more important at high than at low intensity masker levels. Maybe frequency discrimination at the detection moment occurred.

Some priority areas for future research are suggested: analyze the effect of the measurement method by using other psychophysical procedures; evaluate the minimum intensity masker level required to achieve the masking effect; assess the influence the bandwidth of mask signal.

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