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COMBINED EFFECT OF NOISE, INFRASOUND AND VIBRATION ON DRIVER PERFORMANCE

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IMPORTANCE OF REALISTIC EXPOSURE AND TASKS IN A SIMULATOR STUDY

A question with great impact on traffic safety is whether the acoustical exposure of drivers in road vehicles is detrimental to driving performance or not.

The interesting frequency range is approximately 2-20000 Hz, where the acoustical exposure generally is named infrasound below 20 Hz and noise (or sound) above 20 Hz. In modern road vehicles the driving noise level generally is in the range 65-80 dB(A). The sound pressure level (Lin weighting), however, mostly is 90-115 dB at frequencies below 20 Hz, i e in the infrasound range. Physically related to the acoustical exposure is the seat vibration exposure which typically is in the range 0,2-1 m/s^2 on modern, paved roads.

Investigations on the influence of the above-mentioned environmental factors have, so far, either used higher exposure levels or considered only singular exposure types - not the combination of noise, infrasound and vibration which occurs in the real world. Also, studies have almost exclusively been made in simulators where sometimes quite artifical exposures have been used and, mostly, the task has been completely artificial. Lastly, exposures long enough to represent the real world, seldom have been used.

It is of prime importance that both task and exposure conditions be realistic; as indicated in ref 1, where it is shown that the mental load and noise level interact in its influence on driving performance. The experiment described here was designed to fulfil the requirement of realism as well as possible.

DESCRIPTION OF THE EXPERIMENT

The study utilized a driving simulator in which the seat and all instrumentation imitated a bus driver's working place. A moving-road film which was laterally displaced corresponding to the steering of the driver was projected on a screen ahead of the driver (fig 1). Noise and vertical vibrations were produced to match both amplitude and spectra of measured bus environments. An infrasound signal was also added to simulate the extreme low end of the spectrum.

The driver's tasks were chosen as realistic as possible: his primary, continuous task was to steer the "bus" with the smallest possible lateral variation to compensate for a random disturbance. Another primary task - although not continuous - was to break the "bus" at certain instants when a lamp was suddenly switched on. The secondary task was to keep the speed of the "bus" at a certain level. Most real highway driving has exactly these ingredients: To steer, to react fast (break) and to adjust the speed. The performance was measured as the RMS steering deviation from an "ideal" lateral road position, the average reaction time and the RMS speed deviation.

Two levels of noise (80 and 65 dB(A)), two levels of infrasound 12-16 Hz (110 and 80 dB) and two levels of vibration (1.0 and 0.3 m/s^2 RMS) were combined. The low levels were simulating the "best" bus environment found in a previous survey and the high levels were simulating typical "high-exposure" buses. An exposure time of 3 h was used, to simulate a boring long-distance highway drive. The experiment was always started by a 0.5 h pre-exposure test using the "low" exposure levels, continued with a 3 h exposure and ended with a post-exposure test simular to the pre-test. 48 subjects (bus drivers) were participating in the experiments. Each subject had only one exposure, which meant that for each exposure group (8 combinations possible) we had 6 subjects.

RESULTS

For each subject, a normalization of all measurements was made to the results obtained in the pre-exposure i e to each subject's non-exposed, "normal" performance. A variance analysis was run in which the independent variables were noise, infrasound, vibration and time. All possible combinations of these were tested against steering, breaking and speedholding performance. On the 5% risk level the following significant results were obtained:

1. Steering and speedholding performance were impaired with time. However, as a result of the initial learning effect, the pre-exposure performance was somewhat worse than during the main exposure. Interpretation: There is an initial learning effect, except for reaction time, which is more than counterbalanced by some fatigue effect during the exposure and the post-exposure.

2. Increasing noise improved the primary task performance, i e steering. When the high-level noise ceased (in the post-exposure) performance decreased to the initial level. In the secondary task, the decreased noise level led to an impaired speedholding in the post-exposure. Interpretation: Noise of the high level (80 dB(A)) has an arousal effect, which disappears soon after the exposure. The arousal is, however, concentrated only on the primary task (fig 2).

3. An effect similar to that of noise is noticed for the vibrations, where the high level improves performance for the primary task (only). Interpretation: The same as for noise, i e an arousal effect on the primary task (fig 2).

4. A negative effect on performance is resulting from the high-level infrasound. It is noticed for all performance measures in the second half of the main exposure, although it is evident also in the first part for the primary task. It disappears in the post-exposure test where infrasound is low. Reaction time is increased 10-14%

after ca 1.5 h (fig 3). Interpretation: High infrasound impairs performance, especially after some time. A fatigue or drowsiness effect seems to be involved.

5. No interactions between noise and vibration were noticed.

6. An interaction between infrasound and vibrations was noticed only on the secondary task in the post-exposure. High-level vibrations improved a performance which was impaired by infrasound.

7. Noise and infrasound interact on both the continuous tasks. Concerning the secondary task, the interaction is seen in both main and post-exposure, while it is seen only in the second half of the main exposure for the primary task. The combination of high-level infrasound and low-level noise has a highly significant negative effect, while increasing noise eliminates this effect (fig 4). High-level noise appears to impair secondary performance.

8. Heart frequency decreased significantly with time but had only a weak relation with the exposure (the decrease with time was less when noise was high).

9. The subjects answered a questionnaire about their feelings during the experiment. From this it appeared that the high-level noise group considered themselves less drowsy than the low level noise group. On the other hand, those with low noise but high infrasound felt more drowsy than those with low infrasound.

10. The influence on TTS was also tested, although not reported here. Tests of diastolic and systolic blood pressure as well as adrenaline, noradrenaline and creatinine in the urine are not yet completed.

OVERALL CONCLUSION

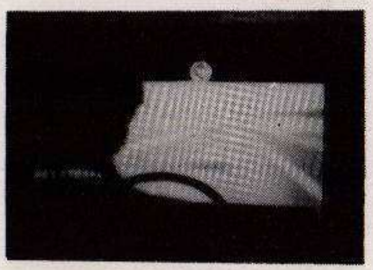
Noise, infrasound and vibrations affect driver performance, at least at the exposures considered here. The influence of noise is to arouse the driver and concentrate his effort on the primary task (which improves) at some expense of the secondary task. A quite similar effect appears to arise from the vibrations considered here. Infrasound has a negative effect on performance, probably due to a fatigue or drowsiness effect after 1-2 hours of exposure. Noise and infrasound thus have opposite effects on performance, which sometimes may counterbalance each other. The arousal of noise may compensate for the drowsiness from infrasound. Masking of infrasound by noise may also be an important effect.

IMPLICATIONS

The effect of relatively high-level noise and vibrations on driver performance is more positive than negative in a long and relatively monotonous journey. Especially it may counteract an otherwise quite serious effect of high-level infrasound. The present trend towards lower noise levels (below ca 70 dB(A)) in road vehicles together with unaffected or even increased infrasound is not desired. A matched reduction of noise and infrasound is better.

REFERENCE

1. Finkelmann, J M; Zeitlin, L R; Filippi, J A; Friend, M A: Noise and Driver Performance. Journal of Applied Psychology, 1977, Vol 62, No 6, 713-718.



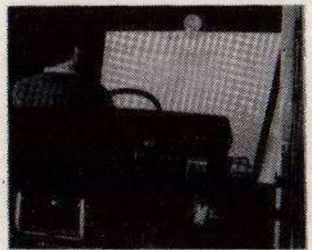


Fig 1a and 1b (above). Part of the driving simulator with its "running" road film.

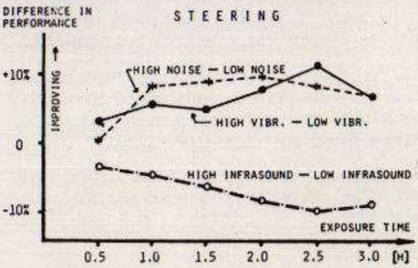
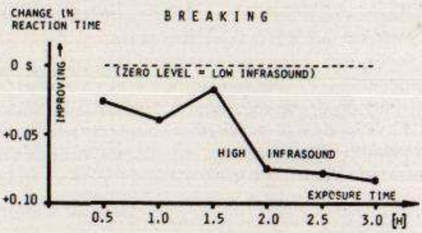


Fig 2 (left). Difference in steering performance between the high-level groups and the corresponding low-level groups. The zero level then equals the performance for the low-level groups.

Fig 3 (right). Difference in reaction time (breaking) between the high-level infrasound group and the low-level infrasound group. The latter has been normalized to zero level. 24 subjects in each group.



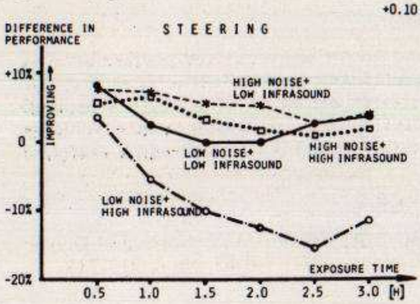


Fig 4 (left). Interaction between noise and infrasound as illustrated by the difference in steering performance between the groups with different exposures. The zero level represents the non-exposed, "normal" performance in the pre-exposure test.