RELATIONSHIP BETWEEN THE PERFORMANCE LEVEL OF RAILWAY DRIVERS AND PARTICULAR ENVIRONMENTAL VARIABLES

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Summary:
Recent research studies show that there is a negative effect on the visual function of railway drivers, which is attributable to the noise level. More precisely in the subjects examined a particular incidence has been found on stereoscopic vision, the capability of recognising colours, twilight vision, night vision and visual function. It has also been proved clinically that tiredness due to noise can be directly associated with loss in the general performance of drivers. As regards visual performance, it has been experimented that particular occipital areas associated with vision are negatively affected by noise, and that at 70-75 dBA examined subjects generally show a phenomenon called midriasis, that has a negative influence on their visual function. It is also true that this phenomenon is significantly manifest with lower but long-lasting noise levels. This disturbance affects the accommodative faculty, the perception of depth and the evaluation of relative distances between two objects moving at different speeds. It has clearly emerged, therefore, how important it can be, in designing safe railway infrastructures, to take into account the level of performance of drivers. This paper first presents an analysis aimed at a preliminary assessment of the different causes of inside cabin noise. Subsequently the effects of this noise on the behaviour of drivers and consequently on their performance are studied. Among the main sources of noise are the wheel/rail contact, the pantograph/line contact, aerodynamic penetration, and the engine. Their incidence varies with vehicle speed. Noise is also affected by several other parameters that depend on the unballasted permanent way, the superstructure, traffic, the vehicle itself and environmental and secondary considerations. Other situations like vibrational stress, shaking and microclimate conditions, that are not always optimal, determine a decrease in the level of performance of drivers. Particularly time is a critical factor in the evaluation of human exposure to whole-body vibration. While the effects of high frequency vibration on visual acuity are not time-dependent, those of lower frequency motion have been shown to vary with vibration exposure time. Other effects on vision, and especially visual tasks, that are greatly affected by attention, may well depend on exposure duration. Studies of this type have been carried out but no substantial proof of their effects is available yet. The level of attention, fatigue, and presence of competitive stimuli interfere with this complex system, and the reaction tends to strengthen the necessity of a more detailed study on the precise nature of these phenomena, as well as the need to search for a law that should be able to quantify, or at least explain, the relationship between noise and vibration and their effect on the visual ability of the drivers.

Keywords: Performance level, Railway drivers, Noise
The study of a railway layout generally prescinds from considerations of a psychotechnical nature, and is mainly based on static and dynamic measurements of the locomotion mechanics of a train in a constrained trajectory, and on time-keeping and respect by engine drivers of other information from traffic control and management centres. In the light of recent railway disasters, however, where the human component was either the direct cause of the accident or the decisive factor in avoiding it, we need to reconsider, or at least extend, our criteria as well as the project approach to the definition of railway layout.

This is even more so in the case of high speed, where the greater safety and comfort level needed to compensate for the effects produced by the extreme running conditions, impose that also the performance of engine drivers, especially in terms of visual perception, level of attention, reaction times, etc. should be taken into consideration.

While travelling, the drivers of any means, whether it be air, land or sea transport, are submitted often for very long times to permanent conditions of a particular microclimate. This microclimate is mainly represented by energy and physical qualities such as: noise, vibrations, temperature, humidity, aerodynamic fluxes, etc.. As both their absolute and relative values change, they contribute to determine the state of well-being of the drivers. Their influence is often quite considerable and depends especially on the duration of their action.

1. Introduction

Though it may not be extremely complex to determine the causes and relative importance of the different parameters that contribute to create the microclimatic conditions (at least the main ones such as noise and vibrational level) to which an engine driver is exposed, their effects on his behaviour and consequently on his performance are not at all simple to assess.

The main noxious factors that may appear and affect the performance level of the driver of a means of transport in motion may be divided into three groups (in this phase of the research we have decided to overlook actions of an essentially climatic nature, such as temperature, humidity, aerodynamic fluxes, etc.). The three groups are as follows:

1) negative effects due to exposure to high levels of sound energy;
2) negative effects relating to the action of vibrational stress;
3) negative effects relating to the combined action of sound energy and vibrational energy.

They usually exert their action in each other’s presence, with mechanisms of summation, interference and reinforcement. They cause various levels of harmfulness: disturbance, annoyance and, in a few cases, even physical damage. The corresponding specific harmfulness accountable to the three defined groups, acts quite similarly, though not in exactly the same way, and varies from person to person, especially at different exposure times.

2. Noise

It has been clinically established that there is a negative effect attributed to the noise level on the functioning of the visual mechanism. More precisely the noise level has been proved to interfere with stereoscopic vision, the capability of recognising colours, twilight vision, and night vision.

It has been experimented that particular occipital areas responsible for vision are negatively affected by noise, and that at 70-75 dBA examined subjects generally show a phenomenon called midriasis (abnormal pupil dilatation), that has a negative effect on their visual function. It is also true that this phenomenon is significantly manifest with low but long-lasting noise levels. This disturbance affects the accommodative faculty, the perception of depth and the evaluation of relative distances between two moving objects.

As regards the negative effects due to exposure to high levels of noise, the most important is, certainly, what is usually termed annoyance, that is the irritation caused by noise, or what
the subject believes is, or may be, caused by noise. Rather than depending on the level of sound energy in the driver’s cabin, annoyance depends on the intrinsic characteristics of noise, such as its spectral composition, its frequency or impulsiveness, the crest factor, modes of emission and also "the subjective interpretation of noise", a rather difficult component to quantify. Annoyance therefore varies from person to person, it is affected by average levels of sound energy and, most particularly, it depends on instantaneous changes in levels of sound pressure. In fact it is recognised that moderate noise levels (60÷70 dBA), but with a crest factor greater than 15÷20 dBA and in the presence of sharp changes in instant levels of sound pressure, may induce neurogenic and neuroendocrine damage in the driver, and are capable of altering his average performance levels, especially when they interact with vibrational stress and climatic discomfort.

It is established that the harmful effects due to noise are closely related to the level of sound pressure as well as to exposure times and times of relative peace. Particular attention in this paper has been paid to studies relating to the effects of noise on the visual functions. From these studies it is deduced, and rather consolidated, that at sound pressure levels of about 75 dBA, glare phenomena in particular travelling conditions are favoured (as, for example, when coming out of tunnels), and abilities related to the perception of relative distance are affected.

Of particular interest are studies on the performance of subjects exposed to the action of noise. The studies show that already at sound pressure levels of about 60÷70 dBA with random variations, they tend to favour a significant reduction in their performance levels.

In a study aimed at pointing out differences in reaction times to specific stimuli (light and sound) in particular subjects exposed to levels of sound energy of varying intensity, it was shown that the reaction time to certain stimuli is affected by the subject's level of attention, his habit to the stimulus and, especially, by his level of fatigue.

3. Vibrational stress

Vibrations on means of transport can cause remarkable disturbance both to drivers and passengers. A particularly interesting factor, that was found in the course of our research, is related to the duration of vibrational stress. In fact, vibrational stress is far more harmful in relation to time of exposure than to intensity.

Generally, vibrations involve the driver’s entire body structure, but though their level of intensity is high, they rarely reach rapidly harmful levels at ordinary running conditions; however, annoyance phenomena due to vibrations are often found in relation to long exposure times. Vibrational levels mainly responsible for effects of kinetopathy are those in the 0.5 - 2 Hz range. These effects vary greatly from person to person, and can be observed at acceleration values as low as 0.01 - 0.1 m/s². In the transverse and antero-posterior directions the most annoying vibrations are between 1 and 2 Hz. An important element that emerges from our research is that related to exposure times. In fact, after 4 hours of exposure at fixed states of vibrational energy, the tolerance levels for exposed subjects are practically halved.

As regards the possible effects of vibrations on vision, several studies have been analysed. These studies show the main factors that may affect visual acuity and performance levels in general. Among these, vibrational frequency and width, visual distance, size, shape, object lighting and exposure times are certainly the most widely known and studied.

The influence of vibrational energy on visual acuity seems to depend to some extent on the vibratory movement of the image through the retina. Generally, in the eye-ball, vibrations (e.g. those transmitted from the driver’s seat to the eye) diminish in intensity and increase in frequency, in relation to the fact that the movement of the image on the retina is affected by resonance of the eye and its components. For this reason it seems extremely important to investigate carefully the existence of resonance frequencies for the human eye.
The specific literature examined clearly shows the existence of a mechanical resonance of the human eye. In vibrational conditions along a vertical axis in relation to the position of the subject (Z axis), mechanical resonance occurs at values of about 30 Hz. In other studies, in which higher frequency fields were analysed (between 15 and 140 Hz), the ability of subjects to distinguish images submitted to them was investigated. Also in this case the results showed strong indications in favour of some form of mechanical resonance between the eye and the retina; this varies significantly from person to person.

As regards the effects related to changes in the distance of sharp vision in the presence of sources of vibrational energy, from an analysis of the literature it emerges that few authors have dealt with such problems; and this is surprising because application of simple mathematical relations shows that a reduction in visual distance should be accompanied by a reduction in visual acuity.

Other experiments in the same field of investigation show that at low frequencies, the high vibrational level used (0.75±1.5 ±g) may cause extended vibrational displacement. Moreover, an analysis of the results of these experiments suggests that, in the case of near objects, this displacement produces a greater loss of visual acuity than in smaller angular displacements for far away objects.

Other experiments show that the lowest vibrational levels (on the Z axis) that cause confused vision, resolve in angular motion of the eyes. For frequencies of between 7 and 60 Hz, it was found that when the distance was changed, the threshold of confused vision was not reached.

As regards the effects of vibrational frequency on visual acuity, they depend on the position of the body and experimental conditions. At certain well-defined conditions, the effect of frequency was partly deviated by the actual transmissivity of the system, and was also found to be a consequence of the relation between acuity and frequency of motion of the image on the retina.

4. Combined effects

As regards the possible interactions between vibrational stress and visual mechanism, eye movement is essentially of two kinds: a compensatory movement and a pursuing movement.

The pursuing reflex is insufficient already in the presence of a vibrational stress of about 0.5 Hz and is totally incapable of helping vision above 3 Hz. These findings have also pointed out that this phenomenon is conditioned by the hearing and balance apparati through impulses of the labyrinth that help eye fixation. It has been observed that subjects with impaired function of the semicircular canals of the ear behave in a different way, depending on whether it was they themselves or the viewed objects that vibrated. This confirms the existence of a vestibulo-ocular reflex in normal subjects.

5. Conclusions

The results of this study confirm the validity of the suggestion that the effects of microclimatic conditions to which an engine driver is submitted should be assessed in greater detail, with the aim of reaching a better estimate of some of the project parameters closely related to performance levels, especially in consideration of the alleged implications between noise, vibrational stress and visual function.

Moreover, the continuous presence of other situations of discomfort, such as shaking, the non-perfectly ideal climatic conditions, etc., is certainly a further source of annoyance that is likely to aggravate performance levels. The level of attention, fatigue, as well as the presence of competitive stimuli interfere further with the complex system of individual reaction and lead to reinforce the necessity of a more detailed and precise study of the nature of these phenomena.
The methodology we intend to follow may be summarised in the following simple and schematic way:

Assuming that the performance level of the engine driver, expressed as the resultant sum of a functional relationship among various energy and physical variables, is \( y \):

\[
y = f (x_1, x_2, ..., x_i, ..., x_n)
\]

where, for example:

- \( x_1 \) = the level of sound energy in the driver’s cabin;
- \( x_2 \) = the level of vibrational energy in the driver’s cabin;
- ...
- \( x_i \) = prevalent climatic conditions;
- \( x_n \) = ............................................

It is also possible to express every \( x_n \) value by a functional relationship of the type:

\[
x_n = p(x_{1n}, x_{2n}, ..., x_{mn}, ..., x_{mn})
\]

where all the generic \( x_{mn} \) values contribute to determine the energy level in the cabin attributed to the \( x_n \) parameter during travelling.

For example, for the above reasons, assuming that:

\[
x_q = \delta E
\]

if \( \delta E \) represents the level of sound energy in the driver's cabin, to a first approximation and admits expression of \( \delta E = h(V) \) as a function of running speed disregarding the noise produced by the outside, the \( h \) functional link may be expressed as:

\[
h = h(\alpha, \beta, \gamma, \tau, ..., \rho)
\]

where

- \( \alpha \) = state of the means of transport;
- \( \beta \) = composition of the train superstructure;
- \( \gamma \) = characteristics of the rolling organ;
- \( \tau \) = coefficient of shape, aerodynamic performance, etc.;
- ...
- \( \rho \) = characteristics of the sound cavity of the driver's cabin.

It is a question of ascertaining in the first place and as thoroughly as possible, which independent variables may alone or together account for the production of sound energy.

Clearly, the same will have to be said of each generic \( x_n \) in order to assess which variables may contribute to determine, and therefore, to change the performance level of the driver. Performance level thus takes on the characteristic features of a proper performance function, that may be related to the treatment of a few deterministic models of behaviour, based on expressions of the kind: "response = sensitivity x stimulus".

The objective of the second phase of the study will be to search for a law capable of quantifying, or at least, explaining the trends in the performance level of an engine driver immersed in levels of sound and vibrational energy of varying intensity and duration.

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