SUBJECTIVE EVALUATIONS CONCERNING EXPOSURE CONDITIONS

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Abstract

Results from our recent observations and interviews point out that people in small and medium sized enterprises and building companies including subcontractors face daily certain combinations of work and work environment related factors. Therefore the issue of interactions between and combined effects of the factors is most important and actual when promoting occupational health and safety in the field, characterizing the reliability of the subjective evaluations and when trying gain better understanding of the fundamental mechanisms of simultaneous and complex actions of the factors in the combinations concerned. Based on numerous studies this paper sheds new light on the questions and topics mentioned above. In addition to noises, vibrations, thermal and lighting conditions, mental and physical work tasks, attention is paid to the meaning of the state of tenseness, smoking and the age of the people. All in all, it turns out that the scores of subjective evaluations varied greatly depending on the type of the exposure combination. In some cases the whole variance analysis model (squared multiple R correlation coefficients) explained up to 90% of the variation in the evaluations of vibration intensity. In particular, young persons rated the additional stress caused by noises high when they were doing physically strenuous work and were simultaneously exposed to vibrations. Elevated temperature increased the experienced subjective stressfulness especially under simultaneous exposure to vibration and noise. Noise, vibration, lighting and smoking in certain combinations or separately affected the subjective ratings concerning either the intensity of noise, vibration and temperature. Smoking alone or smoking together with vibration and noise affected the sensations of upright body posture sway. Furthermore, the state of tenseness seems to modify the subjective evaluations through the changes in hearing thresholds under complex exposure conditions.

(Key words: Complex exposures — Combined effects — Subjective evaluations)

Introduction

Using people as gauges or indicators of their own conditions has lately raised renewed interest among researchers, one central reason for this being that the method is relatively cheap compared to the use of conventional technical measuring instruments. The method has brought up some doubts that self-evaluation might not be reliable or that people would intentionally give misleading responses. My earlier own observations prove that adjusting the scale and calibrating the persons that give the self-evaluations can improve the reliability and accuracy of this method. Yet the reliability estimates often tend to overlook the fact that a subjective evaluation is a complex procedure that involves many factors, while the result of a technical measurement is a simplified description that often applied only to one factor in a clear-cut phenomenon. Thus the data obtained by the two different methods are not similar or share the same dimension.

Our most recent investigations in Central Finland indicate that micro and small-sized productive enterprises, building and subcontracting and in particular multipurpose subcontracting involve many work and work environment related factors to which the employees are exposed (Manninen 1993, 1994). Depending on the product, work method and
duration of the work stage the employee is exposed to similar or dissimilar factors, which in some cases repeat even at short intervals (see also Manninen et al 1993). These are factors and their combined and multiplies effects that labour protection inspectors and occupational health nurses encounter in their work daily during visits to workplaces, while preparing reports and making observations.

In this work I will stick to the traditional method of comparing the variation of self-evaluation results obtained from people of different age groups, both smokers and non-smokers, relaxed or under tension, in carefully controlled exposure situations. The results give significant clues for the development of inspection methods and for the training of personnel for company visits. The results of this report are based on a very extensive set of material, as I shall here summarize the results of different studies.

Material and methods

The results were obtained by several empirical studies conducted in the exposure laboratory under carefully controlled conditions. The exposure system and situations are characterized in more detail elsewhere (Manninen 1989, 1990 a, b, 1992). The subjects gave their evaluations immediately after the exposure situations by comparing their feelings and subjective state to the condition preceding the exposure situation. The exposure situations included whole body vibration, noise, various thermal and lighting conditions, physically and mentally straining work and smoking. The scales used in the ratings were numerical scales with 5 or 6 steps and with verbal descriptions and explanations of the rating tasks. Besides, subjective feelings and changes in the subjects body functions were characterized by such indicators as heart rate and audiometric and stabilometric analyses.

Results

Temperature Evaluations

The temperature evaluations of young subjects (under 25 years) differed considerably from those of middle-aged (under 39 years) and old (over 40) subjects in complex exposure situations mainly in that during consecutive exposure periods middle-aged and old subjects reported warmer thermal conditions (p < 0.001 - 0.005). Smoking alone and lighting had marked effects on the variation of the temperature evaluation results. During consecutive exposure periods the exposure situation was rated the warmer the more strenuous work the test involved. The results of the variance analyses also showed that physical work had a marked effect on the results of the temperature evaluations.

Smoking and lighting together affected the variation of the temperature evaluation results significantly (p < 0.005). Likewise, physical work and vibration had a marked two factor combined effect (p < 0.005), and physical work, mental competition type work and noise had a significant three factor combined effect (p < 0.005) on the results of the temperature evaluations.

With prolonged exposure both the combined effect of competition and noise and that of a mental competition situation and vibration on the thermal sensations were intensified. Age, vibration and noise or age, vibration and mental competition situation constituted the most significant three factor combinations affecting heat sensations.

Vibration Evaluations

Young subjects assessed the intensity of whole body vibration markedly lower (p < 0.001 - 0.005) after every exposure period than older subjects. The results of young and middle-aged subjects did not differ.

In all exposure periods the calm and relaxed subjects differed from the tense and restless in the evaluation of vibration intensity. After consecutive exposure periods the subjects who felt themselves tense and restless at the beginning of the test assessed the vibration during the exposure higher than the calm and relaxed. The strenuousness of physical work did not affect the results of noise level and vibration level evaluations. The combination of vibration and lighting was the most significant combination affecting the variation of the results of vibration evaluations.

Physical work, mental competition situation and vibration were the most significant three factor combinations affecting the results of the vibration evaluation at the beginning of the exposure.

Lighting Evaluations

Smoking alone and smoking together with noise,
vibration and lighting together, and lighting and smoking together affected the results of the lighting evaluations most \((p < 0.05)\).

**Noise Evaluations**

Young subjects estimated the noise level during the exposure situations considerably higher \((p < 0.002 - 0.01)\) than middle-aged subjects. Noise and smoking had significant single effects on the variation of the noise evaluation results.

Noise and vibration had a very significant two factor combined effect on the noise level evaluations. The most important combinations that affected the variation of the noise evaluation results were the three factor exposure combination that consisted of mental competition type work, noise and vibration and the combination containing noise and vibration and smoking \((p < 0.001)\).

**Evaluation of Upright Body Posture Sway**

At the end of an exposure the middle-aged and young subjects also differed in that young subjects reported stronger upright body posture sway than middle-aged. Smoking had a significant effect on the results of the upright body posture sway evaluation.

The results of the upright body posture sway evaluation varied most due to the combined effects of noise and vibration. Noise and smoking also constituted a significant two factor combination that affected the evaluation of upright body posture sway. The three factor combination that affected the upright body posture sway evaluation most contained physical muscular work, noise and vibration \((p < 0.0005)\).

**Evaluation of Tension**

Middle-aged subjects felt themselves more tense at the end of the exposure periods than the youngest subjects. The young subjects also reported themselves to be much calmer than the oldest subjects \((p < 0.001)\).

Another interesting finding was that the subjects who felt themselves tense and restless at the beginning of the exposure period felt even more so at the end of the exposure. In other words, tension increased during the test most among those who were already restless at the beginning of the test.

The tension evaluations recorded after an exposure period are best explained by the combination of mental competition situation, vibration and age.

**Evaluation of Tinnitus**

The ringing of ears was evaluated the more intense, the higher the noise level in the exposure and the higher the \(TTS_2\) values were. In the case of exposure combinations including stochastic broadband vibration, the ringing of ears was estimated considerably higher than in such combinations that did not include this type of vibration.

The most significant combinations affecting tinnitus consisted of mental competition type work and noise, or noise and vibration, while the most significant three factor combination in one test consisted of physical work, mental work and age \((p < 0.001)\) and in another test of noise, lighting and smoking.

**Evaluation of Overall Strenuousness**

Young subjects assessed the overall strenuousness of the exposure situations after the exposure considerably higher than middle-aged subjects.

Those who considered themselves calm and relaxed at the beginning of the exposure situation rated the overall strenuousness considerably lower than the tense and restless subjects. The overall strenuousness increased quite consistently with muscular work load involved in the exposure situation.

The most significant two factor combination affecting the strenuousness sensations in one test consisted of physical work and noise, while in another study it consisted of smoking and lighting. The most significant three factor combination affecting the overall strenuousness contained physical work, mental competition type work and vibration, or physical work, mental competition type work and age \((p < 0.001 - 0.005)\).

**Heart Rate**

Among young subjects the heart rate during consecutive exposure periods was considerably higher than among middle-aged subjects.

Those who considered themselves calm and relaxed had markedly lower heart rates than those who felt themselves tense and restless. As expected, the average heart rates were the higher the more
strenuous physical work was involved, and high heart rates were also recorded when the subjects competed using the choice reaction apparatus for the best time and least errors.

Changes in the hearth rate were explained best by three combinations, the first consisting of physical work, mental competition type work and vibration, the second physical work, vibration and age, and the third mental work, vibration and age.

**Changes in the TTS₂ values**

The subjects who assessed themselves tense and restless after the exposure had after every exposure period considerably higher TTS₂ values (p< 0.005), in particular at 4 kHz, than those who felt themselves calm and relaxed. No such difference could be observed at 6 kHz. The TTS₂ values at 4 kHz were consistently higher after exposures including vibration than after exposures with no vibration.

The changes in the TTS₂ values at 4 kHz were most strongly correlated, on the one hand, with two factor combinations of noise and vibration and, on the other hand, with three factor combinations containing physical work, mental work and age. The changes of the TTS₂ values at 6 kHz were most strongly correlated with exposure combinations consisting of noise, vibration and age (p< 0.05).

**Measurements of Upright Body Posture Sway**

The upright body posture sway (level of variances) was affected most by vibration and lighting (p< 0.001). The two factor combination that affected the upright body posture sway in the X-direction most consisted of vibration and lighting. Noise, vibration and lighting also had a significant (p< 0.05) combined effect on the upright body posture sway both in the X- and the Y-direction.

**Discussion**

The study yielded many results that would be useful in the training of persons to give evaluations of environmental and working conditions and in the desing of the test situations. First of all, the observers should be trained to remain calm and relaxed in completely new situations and while meeting new people. As tension seemed to increase among those who originally felt themselves tense, seemed to increase among those who originally felt themselves tense, it would be a good idea to select such people for the evaluations who are calm and relaxed by nature and familiar with the conditions of the target to be assessed. The reliability of the evaluations is increased greatly if the subjects are non-smoking, belong to the same age group and have a normal hearing.

For example, in assessing the environmental conditions of a certain work cell, the observer can only reach objectivity by placing him/herself directly at the target to be assessed. When assessing the strenuousness of work, the most reliable evaluation by an external observer is obtained if the observer places himself in the work situation and actually performs the work. Another important point is that the observer should give careful consideration to all other factors pertaining to this work situation. As the results presented above and the most typical exposure combinations described in the beginning of this work indicate, such factors as noise, vibration and lighting have their own impacts on the strenuousness of work. The third central procedure for giving reliable evaluations is that both the physical and the mental components of the work are taken into account.

In practice it is often impossible for the assessor to place him/herself directly at the work situation. The job can be too dangerous for an outsider, the external observer may not be able to do the work, or the work cannot be interrupted for the evaluation. It is therefore a common procedure that the observer stays relatively afar of the work cell and performs the evaluation as an external observer, in the actual sense of the term. As expected, the results thus obtained will fail to consider how various factors that are simultaneously present in the work affect its strenuousness.

In these cases one alternative to get reliable information is giving the employee instructions for performing the evaluation self. This is one example that verifies the old proverb that a worker is the best expert of his own work. It should however be ensured
first that the assessor is calibrated and uses agreed reference values and knows the evaluation method in general.

In conclusion it can be stated that subjective evaluation is a fast and economic but also a sensitive method for evaluating the strenuousness of work. In addition to developing suitable evaluation methods, in the future more attention should also be paid on comparing the results of subjective evaluations and measured physiological quantities.

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References


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