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REVIEW

STUDIES OF PSYCHOPHYSIOLOGICAL AND TEMPORAL CONDITIONS OF WORK

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The main areas studied until the 70s were fatigue and rest. Many tests for fatigue were examined, and studies failed to find their practical use. Fatigue grows according to the positive acceleration curve while recovery grows according to the negative acceleration curve. Different mechanisms are involved in intelligence test performance when subjects are fatigued and when rested. Contrary to the pharmacological, psychological stimulants increase performance without adverse effects on the organism. The differences in absenteeism between male and female workers are related to family duties. After the 70s, research was focused on shiftwork. Shiftwork is associated with imposed change in a worker's normal activity pattern. It brings about fatigue, negative moods, and impaired health, sleep, safety, and working capacity. The shiftwork tolerance is connected with introversion, neuroticism, morningness, control of behavioural arousal, and parameters of circadian rhythms. The most important predictors of shiftwork tolerance are dimensions of control of behavioural arousal and morningness, while the most important criterion is sleep quality.

Key words:
circadian rhythms, fatigue, motivation, recovery, rest, shiftwork, sleep, stimulants

PSYCHOPHYSIOLOGICAL CONDITIONS OF WORK

The Laboratory for Psychology and Physiology of Work was the first active laboratory of the Institute for Industrial Hygiene, a newly established institution of the Yugoslav Academy of Sciences and Arts (now Croatian Academy of Sciences and Arts). Namely, an article about Soviet critics of psychological tests in general, led the Occupational Guidance Centre, operating under the Ministry of Work, to its sudden end.

Upon the intervention of professor Domainko, professor Štampar, at that time the director of the School of Public Health in Zagreb, Croatia, reassigned two of the five psychologists from the Occupational Guidance Centre (Z. Bujas and B. Petz) to the Institute of Industrial Hygiene which was in the process of foundation. As Z. Bujas had already been a senior lecturer at the Faculty of Philosophy, he was assigned to the position of the laboratory head on part-time basis, whereas B. Petz obtained full-time employment.

The laboratory had been situated on the ground floor of the School of Public Health at the time, that is, until the new building of the Institute was completed. It was there that the first experiments on static work (1) and experiments on the effects of physiological stimulants (hyperventilation and dark adaptation) and some preliminary experiments with pharmacological stimulants took place. Most experiments measured the energy consumption in investigated subjects using the Benedict-Roth respirometer for the basal metabolism which had been available thanks to professor Štampar.

Z. Bujas had led the research team of the Laboratory of Psychology and Physiology of Work until the seventies. His broad interests (beyond his main research in psychophysics and psychophysiology of sense organs) led to broad-based research projects and it was thanks to his divergent approach and incessant curiosity that the Institute introduced fairly many new research initiatives, investigating mainly work and fatigue, as well as various forms of so called stimulants affecting the efficiency at work and fatigue in men and animals. The divergent approach resulted in revelations that would probably – using the classical methods – have remained unknown to us.

Particular approach

The investigation of fatigue may serve to illustrate a typical example of that particular approach. The notorious fact is that not a single person has yet been able to tell what exactly fatigue is, how it manifests itself, and how to measure it. Investigating the symptoms of fatigue, the Laboratory of Psychology and Physiology of Work stood out at the time as the single laboratory in the world to conduct experiments which shed a completely new light on the issue of fatigue. The regular scientific approach at that time consisted of a comparison between different physiological and psychological functions performed in the state of rest and fatigue. Differences in the functional performance were taken as proven symptoms of fatigue, whereas lack of difference in one function indicated that fatigue did not manifest itself through that function. Yet, the problem called for more complex and finer analysis than that, that is, for the factor analysis of functions involved in the state of rest and fatigue. Briefly, it is conceivable that work outputs do not differ between the states of rest and fatigue, but that the difference may lie in the mechanisms leading to such work output. The Laboratory of Psychology and Physiology performed an experiment with fatigued and rested subjects, applying a comprehensive intelligence test which consisted of subtests intended to measure diverse »factors« such as the reasoning factor, spatial factor, perceptive factor, numeric factor, and so on. The results were compared between two groups of subjects (the fatigued subjects had to remain awake all night and be physically active) who showed practically identical scores, not only in mean values, but also in standard deviations. The classical approach would in such case come to the conclusion that it is not possible to establish any difference in the test scores between the rested and the fatigued subjects. Bujas' approach, however, went farther, as he wanted to see whether the same result was achieved through the same mechanisms or not. The factor analysis (cluster analysis) showed that those results were achieved through different mechanisms. In rested subjects »factors« correspond to the expected tasks, that is, the reasoning factor is involved in the solution of reasoning tasks, the numeric factor in numeric tasks, spatial factor in spatial tasks, and so on. Yet, in fatigued subjects, those factors are »broken down«. The task is solved through other factors, obviously not corresponding to the tested factor (2). To cut the long story short, the experiment has shown that fatigue »disintegrates« the factors expected for task solving, and reorganises (»integrates«) them at a different level (3). This was partially confirmed by the results of so many (futile) attempts to find an applicable test for fatigue; namely, despite the well-known fact that heavy fatigue decreases performance in most activities (sometimes the assumption proves completely false in lab conditions), there are some activities such as perceptive illusions which even increase the performance in the state of fatigue! Charpentier's illusion, for instance, is a misperception of weight of two equally heavy boxes where the smaller box is normally perceived as heavier, but the illusion becomes less common in the state of fatigue.

Another good illustration of the Bujas' divergent approach is his testing of once a very popular test for fatigue, that is, the »critical fusion frequency« (CFF). The test consisted of recording the frequency at which a human starts to perceive a blinking light as constant. The usual values ranged between 30 and 40 blinks a second. In search for symptoms of fatigue in the central nervous system, some authors found that the critical fusion frequency would fall significantly in fatigued persons, that is, by a few Hertz. The drop was attributed to changes in the brain function instead of peripheral changes in the eye. To make sure that the changes were indeed central, Bujas conducted experiments that excluded the eye function. The experiments involved electric stimuli to the temple – that is, as near as possible to the visual nerve – which varied in frequency and produced a blinking effect (»phosphene«). Subjects were fatigued in many ways; for instance, they were kept awake overnight or had to run up and down a 1,000 metres high hill. Yet, the critical fusion frequency did not change, proving that the changes caused by the light stimuli were in fact peripheral and not central (4). The finding is supported by the fact that the changes in the CFF were mainly limited to post office and other office personnel who generally work with visual information.

Workload, endurance, and recovery

A separate group of experiments involved carefully prepared and performed experiments on static work concerning the relationship between workload and endurance on one side and workload and the speed of recovery on the other (5–7). Those experiments showed that the process of rest follows the curve of negative acceleration; it is quick at first and slower toward the end. In other words, double time for rest does not entail twice as efficient recovery, but significantly less. The finding definitely confirmed the rule that it is far more sensible to take several short rests instead of a long one. The same was later confirmed by our experiments taking oxygen debt or residual abilities of a subject as the criteria for degrees of fatigue (8, 9).

Development of fatigue

It was equally interesting to see how fatigue grows during work. Regardless of the fact that, so far, it has been impossible to measure fatigue for practical application, the measurement of the degree of recovery upon qualitatively and quantitatively different kinds of rest allows indirect estimation of fatigue. One of comprehensive experiments quantitatively measured the recovery after work of different length. The experiment showed that fatigue grows according to the positive acceleration curve, that is, slow at first and faster toward the end. The finding confirmed again the wisdom of the advice that it is better to take several short breaks at work instead of one long, and thus make better use of the first (early) stage of rest which allows the quickest recovery at any level of fatigue (10).

Active rest

The investigation of rest particularly addressed the issue of the active rest. Sechenov defined it as the activity of those categories of muscles which were not involved in operation that led to fatigue (e.g. after work with the right arm, active rest would consist of work with the left arm). It is now well known that such active rest leads to improved and quicker recovery of tired muscles than does the »empty pause«, that is, complete inactivity. One of our experiments proved that it was possible to extend the definition of active rest beyond the activity of other groups of muscles. The experiment involved subjects who rode a bicycle-ergometer until they were exhausted. Breaks in between successive activities either involved »empty pauses« (serving as control experiment) or the same activity (i.e. pedalling), but with significantly reduced intensity. The reduction in workload proved to lead to better recovery than did complete inactivity (11).

Different mechanisms under high and low load

These and related experiments conducted by our Laboratory brought to the conclusion: there was a significant difference in the nature of static work under low and under high workload. Opposite to the well known Bykov's opinion that a high-load static effort led to peripheral (muscular) changes and low-load effort to peripheral and central changes, our experiments showed that high-load effort tended to be short and led only to central changes whereas low-load effort tended to last much longer and led both to central and peripheral changes.

Another experiment proved that there were two different mechanisms of fatigue involved in the process and that, in effect, no transfer of training from high to low-load effort did occur in static work. Subjects who had been trained for high workloads and those trained for low workloads for a month achieved endurance several times greater than without the training, yet limited to that type of activity for which they had been trained. In other words, training for endurance at high workloads did not improve endurance at low workloads and *vice versa*. Regardless of the fact that the same group of muscles (fist muscles, as the work was performed on a mercury dynamometer) were involved at both workloads in the experiment, the results bluntly showed that the two operations involved different mechanisms. (12).

Those results were corroborated by experiments with voluntarily or electrically induced ergogrammes. The experiments started from the assumption that voluntary ergogrammes were controlled by the central system whereas electrical ergogrammes were controlled peripherally, and that the ergogrammes controlled centrally would be (due to their finer structures) more sensitive to changes in workload than the ergogrammes induced electrically. The results of the experiments confirmed the assumption (13, 14).

Another experiment, rather interesting from the physiological point of view (and with results generally not known to physiologists of work and sports), showed a surprising behaviour of the maximal pulse (the pulse at which a subject stops physical activity due to exhaustion) in the course of training. Training was expected to push further up the limit of the maximal pulse or, if that remains the same (as a physiological limit), prolong the activity required to achieve it. Yet, the results showed a decrease in the maximal pulse by about ten beats a minute in highly trained subjects (15). This finding corroborates the assumption that pulse may limit the endurance in an untrained man, but that highly trained people are limited by factors other than pulse (such as muscle metabolites), as it can still grow.

Tests for fatigue

A specific part of our research interest lied in testing the alleged tests for fatigue (such as critical fusion frequency, »recovery pulse sum«, and so on) and looking for new ones that would match the practical requirements of measuring fatigue. Needless to say, all such attempts were futile and not to this day has a test for fatigue found its practical use (3, 16, 17).

The very fact that so many attempts to find a univocal test for fatigue proved futile suggests that what we call fatigue may be something other than a single category, but rather a variety of more or less independent phenomena which vary according to the type of work, working conditions, and the worker's individual characteristics (3).

It is true that some changes have been found in the state of fatigue such as the increase in the EEG alpha-index (19), a decrease in the Charpentier's illusion, changes in the stereoscopic view (20), and reproduction of the arm movements (21), yet all these symptoms are limited to laboratory conditions and have no bearing whatsoever in the real life. Not even in laboratory conditions are these quantifiable with precision.

Pharmacological and psychological stimulants

One of the research interests of the Laboratory for Psychology and Physiology of Work was the influence of stimulants on work and prevention of fatigue. Particular attention was paid to pharmacological and psychological stimulants. The most frequent pharmacological stimulant used in our experiments was a Benzedrine™ product with the brand name Fenamine®. Psychological stimulants were competition (with one's own or other person's results), awareness of one's earlier performance (endurance), awareness of time elapsed, and so on (22–24). The basic issues raised by those experiments can be summed up in the following two questions: do stimulants increase performance, and if they do, does this happen at the expense of the organism or there is no adverse effect involved?

The answer to the first question was clear; pharmacological and psychological stimulants did increase performance significantly. It was less clear which of the two had stronger effect, as it depended on the degree of motivation or on the received dose of Fenamine® (subjects in our experiments always received 15 mg). Some animal experiments (see below), however, suggest that in the state of maximal psychological stimulation (struggle for survival), no pharmacological stimulant can further increase the effect achieved by psychological stimulation.

As regards the second question, our experiments showed that pharmacological stimulants increased the performance at the expense of organism; oxygen debt increased under the influence of Fenamine®. The phenomenon is to be expected because oxygen consumption increases with duration of work, that is, more work equals greater oxygen consumption and greater oxygen deficit which is to be compensated through greater oxygen debt. Psychological stimulants, on the other hand, also increased performance, but not the oxygen debt. The fact obviously challenged our notion of oxygen consumption at work (i.e. longer the work, greater the consumption) and we conducted several experiments to measure oxygen consumption in the course of work. The experiments showed that the organism consumed less oxygen when psychologically stimulated. In other words, psychological stimulation affects the body in such fashion as to economise oxygen consumption at work. It is, then, a fair assumption that prolonged work under psychological stimulation produces as much oxygen debt as prolonged work without such stimulation.

Beside oxygen consumption, the economising property of psychological stimulation was proven by a method applying the criterion of maximal remaining strength in the organism (22).

To sum up, while pharmacological and psychological stimulants do increase the capability of an organism, the pharmacologically stimulated increase occurs at the expense of that organism (that is, the organism has to pay for what it received) and the psychologically stimulated increase does not. The fact that pharmacological and psychological stimulants set to motion similar physiological mechanisms (that is, adrenaline boost) raised the question why the two differ in energy consumption. The only reasonable hypothesis available at the moment (though it still needs experimental verification) is that psychological stimulants set to motion mechanisms of mobilisation in the organism naturally, whereas pharmacological stimulants force such mechanisms into motion unnaturally. Natural mobilisation, hence, functions in a more economic way.

A subsequent major experiment with psychological stimulation concerned purely psychological aspects of competition. The purpose was to isolate the impact of motivation on performance (25). It is common experience that differences in performance between the winning and the losing side are substantial, yet these may reflect differences in capability as well as in motivation. To exclude the former and focus on the latter, we conducted a major experiment with children in a primary school who were distributed in two equally capable groups (»A team« and »B team«) on the basis of a rather simple 15-minute algebra test. The teams were then briefed about the competition that was to take place every day for the following two weeks. The study design involved two experimental scenarios. In the first scenario, the »B team« was always the winner, which gradually led to the increasing difference between the teams. Of course, the results told to the teams were set in advance, and the children were not aware of the actual results of their performance. In the second scenario, the test results of the previous day and cumulatively up to that day, differed little, and the teams would alternate in the lead without regularity or a pattern. The results of the study clearly showed that in the second scenario performance grew steadily in both teams (both in male and female classes) and did not have a tendency to plateau. In the first scenario, however, the performance of the »winning« team grew indeed, whereas the »losing« team soon lost motivation and its performance dropped markedly. A few days later, the »winning« team became convinced of imminent victory, started to lose motivation, and the performance plateaued.

It is worth mentioning that the experiment gave an interesting insight into defence mechanisms of frustrated children; the »losing« teams of boys showed aggression (hostility toward the »B team«) or rationalised the »defeat«. Girl classes showed the opposite behaviour; the »winning« teams would start to sympathise with their opponents and wish them occasional victory. The experiment unmistakably led to the conclusion that the best performance was achieved where the competitors had comparable abilities and their results differed as little as possible.

Methodological problems with stimulants

Ever since the beginning, the Laboratory of Psychology and Physiology of Work has investigated several other issues of methodological concern. One worth mentioning is the investigation of fatigue and rest performed on a great number of laboratory rats in order to verify the hypothesis that pharmacological stimulants interfered with the restitution. It took substantial time for us to develop the most acceptable technique for testing the maximal endurance in the animals (swimming with a load) because the rats soon devised a few tricks to make the experimenter pull them out of the pool long before they were completely exhausted. The experiment also showed that rats swam equally long with or without Fenamine® stimulation. The only explanation we were able to produce was that external stimulation bore no further effect on endurance when it came to struggle for survival.

Questionnaire application

The Laboratory also sought the best way to apply a questionnaire (26). Generally, there are three ways to do it: in the form of the so called »free group application« (the subjects receive a basic instruction and then work through the questions setting their own pace), in the form of a »guided collective application« (the experimenter reads one question at a time waiting for the group to reply before carrying on), and in the form of »individual interview« (the experimenter goes through questions with each subject individually and records her/his replies). »Free group application« showed the lowest performance, that is, many questions were left unanswered. The »guided collective application« and the »individual interview« yielded reliable results, yet the latter is far less practical and considerably more time-consuming. This is why our later inquiries largely applied the »guided collective application« procedure.

Absenteeism

Further investigations concerned absenteeism in a major company from the city of Zagreb, Croatia. The findings showed intriguing differences between men and women with respect to their responsibilities in the family. Singles led in absenteeism among men and were at the back of the line among women. Men with larger families were recorded the fewest cases of absenteeism, whereas the opposite was true for women with big families. The differences should be attributed to the adopted role of a woman in a family (27, 28).

TEMPORAL CONDITIONS OF WORK

At some point, the Laboratory investigated the attitude of nurses towards work on night shifts, using a specially devised and verified questionnaire for the purpose (29). This was one of the studies that shifted the focus in the Laboratory toward issues related to temporal conditions of work, particularly shift work, marking thus the years that would come with intensive study in the field.

Shiftwork has been associated with a number of physiological, social, and psychological problems in humans. Its main feature is the imposed change in the normal activity pattern. The change is especially marked on night shifts when workers have to work and sleep in wrong circadian phases. In slowly rotating shiftwork schedules circadian rhythms tend to adjust their phase position in order to meet the needs of a new activity pattern imposed by shiftwork. Yet, various physiological and psychological rhythms are capable of phase shifting at different rate, and some of them adjust very slowly to the imposed change in the activity pattern. The consequences of different rates of adjustment are abnormal phase relationships within circadian rhythms of a person and abnormal phase relationships between circadian rhythms of a person and rhythmic variations in the environment. In fast rotating shift systems, circadian rhythms have little possibility to change their phase position and the workers' circadian rhythms are out of phase with the imposed activity pattern during night shift all the time. A similar, though minor, change in the activity pattern is needed on morning shifts, especially if the work starts early. Therefore, there is a long lasting and recurrent need for shiftworkers to adjust their living routine to particular shift schedules. The most obvious consequence of abnormal phase relationships of circadian rhythms relative to rhythmic variations in the environment is disturbance of sleep. Duration and quality of sleep during day after night work cannot approach the level obtained at night, even in permanent night workers.

Deprivation of sleep and phase shift of sleep/wake cycle bring about various symptoms of fatigue, irritation, and other negative moods which can be connected with various health problems, safety, and reduced working capacity. In such states workers have difficulties in fulfilling their roles as husbands, fathers, friends, and citizens.

There are great individual differences among workers in tolerance of shiftwork. Many of them cannot tolerate shiftwork very soon after they start to work by such schedules; others can sustain shiftwork until the age of forty or fifty without having the symptoms of intolerance. There are some workers who are able to tolerate shiftwork all their active life without related medical problems or complaints.

Earlier studies of workers' characteristics gave limited explanation of individual differences in tolerance of shiftwork. The purpose of our studies was to find out which personal and rhythm's characteristics could give more useful information in explanation of differences in tolerance of shiftwork. Therefore, the major part of our cross-section and prospective studies aimed to establish the relationships between various measures of individual differences and indices of tolerance of shiftwork.

Methodological issues

In measurements of circadian rhythms of physiological, psychological, performance, and behaviour variables, we used the constant routine technique, that is, the measurements were performed in conditions that enabled control of noise, illumination, activity, posture, sleep, food intake, and microclimate, which could otherwise influence the results of the dependent variables under consideration.

The curve of raw data, which were obtained over a 24-hour period, was smoothed using the mathematical curve-fitting procedure. The procedure produces three parameters which describe the basic features of the circadian rhythms: (a) mesor, or the average value of the fitted curve; (b) amplitude, defined as a value from the peak to the trough of the fitted curve; and (c) acrophase, which is defined as the point on the fitted curve at which the maximum value occurs.

We used the »guided collective application« procedure for all our questionnaires, which enabled collection of more reliable data than with some other conventional techniques of gathering data (26).

Studies of individual determinants of shiftwork tolerance used the factor analytical technique (principal components analysis). It enabled detection of the factor structure of each independent (predictor) and dependent (criterion) measure. The canonical analytical technique was used to assess the relationship between a set of our predictors and a set of criterion measures. It provided information about the nature of relationships or patterns of interdependency that joined the two sets of variables, and gave information about the number of (statistically significant) links between the sets.

Shiftwork and productivity

Field studies could not demonstrate any reliable difference in productivity between shifts. However, experimental studies of circadian variation in various physiological and psychological variables related to work and work efficiency indicated that there should be a reliable difference in productivity between shifts, and more specifically, that the night shift productivity should be the lowest. We set up two studies to test the hypothesis. One was a field study in which the productivity of female shiftworkers, who worked by a weekly rotating three-shift schedule, was recorded in well-controlled conditions. The other was an experimental study in which we recorded the efficiency in various tasks during work organised by the same three-shift schedule.

The first study was conducted in an electronic industry where women manufactured capacitors. This was a simple psychomotor task requiring hand and finger dexterity (30). In the study, it was possible to measure the productivity of each worker by counting the produced capacitors. In the second study, the performance efficiency in various tasks (letter cancellation, card-sorting, adding, and simple and four-choice reaction time tasks) was measured in a laboratory setting for each working spell three times a day, five days a week (31).

The results of both studies were very similar. The productivity and the efficiency of the afternoon shift was the highest and the productivity and the efficiency of the night shift the lowest. The productivity of the night shift in the field study was the lowest, in spite of the fact that for the same productivity on the night shift workers were paid 20% more than on other shifts.

These results agree with results of all our laboratory studies of circadian variations which almost invariably indicate that the best performance occurs in the afternoon and early evening, and that the lowest performance occurs at night.

Workers' characteristics and shiftwork tolerance

Various studies indicate that some characteristics of workers could be related to their tolerance of shiftwork. This is particularly true for characteristics related to the amplitude, level, stability, and phase position of the workers' circadian rhythms. The internal desynchronisation of circadian rhythms has frequently been associated with intolerance of shiftwork. Our studies measured individual differences in characteristics such as morningness–eveningness, neuroticism, introversion–extraversion, A–B type of behaviour, as well as control of behavioural arousal, rigidity of sleeping habits, languidness, and flexibility of behaviour.

Prior to studying a relationship between morningness–eveningness and tolerance of shiftwork, we extensively examined the validity of a morningness–eveningness questionnaire in a laboratory study. The study of circadian variations in activation and performance of the morning-active and evening-active individuals and of the introverted and extraverted individuals showed that morningness–eveningness was more important in differentiating people with respect to their phase position than the introversion-extraversion. Performance efficiency and the level of activation of the morning-active subjects were higher during daytime but lower in the evening and over night than of the evening-active subjects (32).

We used three groups of indices of tolerance of shiftwork in our studies: health indices, sleep characteristics, and specific indices of tolerance of shiftwork. Health was measured using the following scales: generally poor health, musculo-skeletal complaints, respiratory complaints, psychosomatic-digestive complaints, and digestive problems. The characteristics of sleep, that is, quality and duration of sleep at various phases of shift cycle, as well as the more specific indices of tolerance of night and morning shift were the most important indices of tolerance of shiftwork.

All these measures were used in a cross-sectional study with experienced shiftworkers and in a longitudinal study with young workers starting shiftwork for the first time.

Shiftworkers worked in a 2:2:3 continuous three-shift system, with shifts starting at 06:00, 14:00, and 22:00. Workers rotated shifts in the order of mornings–afternoons–nights. The main interest of our studies were the links between measures of individual differences in characteristics of shiftworkers (predictors) and measures of tolerance of shiftwork (criterion variables) in order to find out concurrent and predictive validity of individual difference measures for prediction of tolerance of shiftwork.

The most frequently used variables in shiftwork studies and supposedly the most affected by shiftwork are health and sleep. Several studies showed that, as a function of work experience, health of shiftworkers deteriorated at a higher rate than the health of workers who did not work shifts. In our study, however, the difference in health between younger workers was small because their experience with shiftwork was still too short to produce effects. There is evidence that age has an important role in the manifestation of intolerance of shiftwork and that the signs of intolerance of shiftwork usually become apparent in late 40s or early 50s. That is the reason why our longitudinal study has not shown the presence of reliable links between predictors and criteria of tolerance of shiftwork so far (33). Such links are more likely to be detected in future, after a longer experience with shiftwork, especially when it has been established that our predictors and criteria have a high temporal (ordinal and structural) stability.

The main differences between tolerant and intolerant shiftworkers in our cross-sectional studies concerned health and sleep variables, or more specifically, sleep quality and duration, general health, and psychosomatic-digestive problems. These variables are closely related to the quality of life of shiftworkers. The only significant difference between tolerant and intolerant shiftworkers found in our studies was in the variables of mood. Tolerant shiftworkers reported a higher level of positive moods and a lower level of negative moods and fatigue than intolerant shiftworkers over a 24-hour period (34, 35). Therefore, a higher level of positive moods, a lower level of negative moods and fatigue, as well as better sleep quality and health are what makes the everyday quality of life of tolerant shiftworkers better than that of intolerant shiftworkers.

Sleep quality was the most important criterion variable in determining tolerance of shiftwork. It had the highest canonical factor loading in canonical analyses of the cross-sectional study (36). The canonical analyses indicate that sleep duration, especially on afternoon shift days and days off, could have an important role as an index of tolerance of shiftwork in a rapidly rotating shift system. Longer sleep during afternoon shift days and days off efficiently offsets the negative consequences of short morning and night shift sleeps and prevents the accumulation of sleep deficit (36).

The third group of tolerance criteria used in our analyses, besides health and sleep measures, were specific shiftwork tolerance indices which are particularly related to workers' behaviour and mood during night or morning shift days. Namely, the results of our studies indicated that morning shift tolerance and night shift tolerance were hardly related at all. Moreover, morning shift tolerance was related to different individual difference measures than night shift tolerance. Therefore, it is questionable whether we may use a general term such as tolerance of shiftwork or we need two more specific concepts: morning shift tolerance and night shift tolerance. This brings forth the issue of effective selection of workers for various shift systems. That is, if there are predictors that are more specifically related to morning shift tolerance and others more specifically related to night shift tolerance, then the use of these specific predictors will make more efficient the selection of a permanent shiftwork system than of a rotating shift system (37).

Almost all measures of individual differences in characteristics of workers used in previous shiftwork research were studied as predictors of tolerance of shiftwork in our longitudinal and cross-sectional studies. The canonical analyses of the results of our cross-sectional study indicated that relaxation and efficiency were two most important individual difference measures (both from the Behavioural Arousal Questionnaire).

In the longitudinal study, young workers reduced their overall sleep during the first five years of shiftwork, and especially the sleep on afternoon shift days. While sleep duration shows some changes over the first five years spent in shifts, sleep quality does not seem to change at this early phase of exposure to shiftwork (38).

Some studies indicated that napping depended on sleep loss. Unlike non-nappers, nappers had a short main sleep before their morning and night shifts. Our cross-sectional study, however, showed two opposite tendencies in an age-heterogeneous group of shiftworkers. Workers who napped on morning shifts slept longer than non-nappers, but those who napped on night shifts slept shorter than non-nappers. In addition, napping in both shifts was more common in older workers (39). However, in our longitudinal study we found no evidence that young workers of the same age napped to compensate for a short main sleep. These results indicate a need to control for the effect of age when napping is analysed in a mixed-age group.

The longitudinal study showed that young shiftworkers who slept below the average on days of the morning shift increased their sleep on days of the afternoon shift more than did those who slept over the average on days of the morning shift. Even stronger relationship was found between sleep duration on night shift days and increase of sleep on days off, indicating that compensation for loss of sleep was more pronounced when reduction of sleep was greater. The above relationships strongly support the notion that sleep in more favourable conditions makes up for reduced sleep in less favourable conditions. Similar compensations for reduced sleep were found in our cross-sectional study of sleep in shiftworkers with longer shiftwork experience (40). At the same time it was possible for a worker to show a tendency, although a weak one, toward relatively long or short sleep irrespective of sleep conditions.

Special psychometric problems arise with the attempt to assess prognostic validity of various measures of individual differences. In all longitudinal studies there is an implicit assumption that both the measures used as predictors and measures used as criteria are temporally stable over the working span and retain similar relationship in spite of many internal and external changes in the life of shiftworkers. Yet, there is substantial empirical evidence to question this assumption.

Such problems are especially important for the measurement of individual differences in young, twenty-odd-year-old shiftworkers. There is evidence that middle-aged and older adults typically show high levels of stability of individual differences in many characteristics. However, appreciably lower levels of stability were found in studies in which college-aged individuals were followed. The problems are multiplied by the fact that criterion measures are under the influence of changes in a shiftworker's role in everyday life. For instance, after finishing high school, a man has to serve in the army, and then to start, for the first time, regular professional activities. Additional efforts are required to get a good position within the organisational hierarchy, to find appropriate housing and create such living conditions that would make a person able to cope with sleeping at odd hours and to find an accommodating sexual partner and perhaps a partner to establish a family. All these bring about rather great changes in the everyday life of a shiftworker, which can adversely affect the stability of the criterion measures (41, 42). These changes cause stress with which workers cope through appropriate mechanisms in order to avoid accumulation of its negative consequences. Later, when children grow up, the financial situation becomes stable, and the living conditions are such that the shiftworkers no longer need to put an extra effort to solve everyday problems in their free time, they can settle down and establish a rather regular pattern of life.

Concurrently, biological changes related to age make older workers more sensitive to adverse effects of shiftwork than their younger colleagues. In combination with a different level of coping capacity, the adverse effects of shiftwork can accumulate at a different rate in different age groups of shiftworking population, partly depending on individual characteristics. Thus, the difference between tolerant and intolerant shiftworkers becomes more pronounced and is easier to detect as the shiftwork experience grows. This is why our longitudinal study should continue the follow-up until the subjects reach older age.

Collaboration with foreign institutions

The Laboratory had close contacts with many foreign institutions which studied problems related to shiftwork in USA, United Kingdom, Germany, and Sweden and had participated in the work of the Scientific Shiftwork Committee of the International Commission on Occupational Health for many years. The Laboratory had the opportunity to organise the 10th International Symposium on Night and Shiftwork in Cavtat in the end September 1991, but it had to be relocated to Sheffield because of the Serbian aggression in our country. Many well-known scientists visited our Laboratory: Professor Joseph Rutenfranz, Professor Rutger Wever, and Michael Colligan. Professor Simon Folkard, a member of the Medical Research Council, Perceptual and Cognitive Performance Unit, University of Sussex, spent a year (1985/1986) working in our Laboratory. David Cariani, University of Rome, intended to spend a year in our Laboratory in 1992, but the war turbulences in the country discouraged his arrival.

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Dissemination of knowledge about work psychology and its application

The Laboratory scientists have published many popular papers related to work, rest, fatigue, safety, health, and biological rhythms with the intention to introduce general population to a variety of psychological and physiological problems of the working population and to suggest solutions (e.g. 43, 44). They organised or actively participated at many meetings in the country and abroad. In 1972, the Laboratory in collaboration with the Croatian Psychological Society organised the Symposium on Psychological Aspects of Shiftwork (45). One of the purposes of the symposium was to create conditions that would encourage investigation of shiftwork in the country. Soon after the symposium, it was possible to conduct a study of shiftwork productivity in RIZ electronic company in Zagreb (31), as well as cross-sectional and longitudinal studies of relationships between individual characteristics and tolerance of shiftwork in workers of INA Oil Refinery in Rijeka (33, 36–42). The studies would have been impossible without the support of the Refinery staff and of a team of psychologists and occupational health physicians from the company.

During the last 20 years many empirical studies were published on circadian variations in alertness, readiness for work and work efficiency, sleep and wakefulness, and other functions related to shiftwork. As a result of these studies, two questionnaires (Morningness–eveningness Questionnaire, Behavioural Arousal Questionnaire) which proved most useful in selection of potential shiftworkers, have been published by a Croatian publisher Slap. Recommendations for managers and workers were published in order to decrease psychological, physiological, and social problems of shiftworkers as much as possible. The intention of a paper published in 1991 (45) was to provide helpful recommendations to managers in organising shiftwork and health protection in such fashion as to prevent potential health impairment and to facilitate recovery from the consequences of shiftwork. The same was the purpose of a 1992 booklet containing guidelines to workers and members of their families for coping with various problems associated with shiftwork (46).

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Sažetak

ISTRAŽIVANJA PSIHOFIZIOLOŠKIH I TEMPORALNIH UVJETA RADA

Glavna područja rada Laboratorija za psihofiziologiju rada u prvih dvadeset godina bila su ispitivanja umora i odmora. Provjeravano je mnogo standardnih »testova umora«. Pokazalo se da još nema testa kojim bi se umor mogao uspješno mjeriti u praksi. Utvrđeno je da umor raste krivuljom pozitivne akceleracije, a oporavak se zbiva krivuljom negativne akceleracije. Umorni ispitanici rješavaju testove jednako uspješno kao i ispitanici koji nisu umorni, ali ih rješavaju uz pomoć drugih mehanizama. Izgleda da su u usporedbi s farmakološkim stimulatorima, psihološki stimulatori prirodni način mobilizacije organizma, pa stoga djeluju na ekonomičniji način. Rađena su istraživanja na izostancima s posla. Nađeno je da kod muškaraca najmanje izostaju samci, najviše osobe s većim obiteljima, a kod žena je obrnuto.

Od 1970. godine sustavno se ispituju cirkadijurni ritmovi i smjenski rad. Utvrđeno je da smjenski rad zahtijeva neprekidne promjene u ritmu budnost/spavanje. Ove promjene mogu izazvati umor i druga negativna raspoloženja koja su povezana s narušenim zdravljem i poremećenim spavanjem te smanjenom produktivnošću i sigurnošću. Posebna pozornost posvećena je longitudinalnim i transverzalnim ispitivanjima povezanosti osobina radnika s tolerancijom prema smjenskom radu. Ispitivane su osobine kao što su jutarnjost-večernjost, introverzija, neurotizam, plastičnost ponašanja te parametri cirkadijurnih ritmova (amplituda, akrofaza i mesor). Na osnovi kanoničke analize utvrđena je povezanost između određenih karakteristika radnika (prediktora) i indikatora tolerancije (kriterija). Utvrđeno je da su najvažniji prediktori tolerancije prema smjenskom radu dimenzije plastičnosti ponašanja i jutarnjosti-večernjosti, a najvažniji kriterij tolerancije kvaliteta spavanja.

Ključne riječi:
cirkadijurni ritmovi, motivacija, odmor, oporavak, smjenski rad, spavanje, stimulatori, umor

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