METHODOLOGICAL ISSUES AND PROBLEMS IN SHIFT WORK RESEARCH

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Let us assume we have complete freedom for designing a field study on shiftwork research. How would we start it? One obvious way would be to take a representative sample of people who are beginning to work and divide it randomly into groups who work in different kinds of shiftwork and control groups who perform similar work, but not on shifts. We then would have to keep all environmental factors constant and follow the groups up prospectively by taking measurements of all relevant social, psychological, physiological, and medical variables. Finally, we would have to evaluate the data by complex statistical analyses in multifactorial designs (different kinds of work schedules, different kinds of shiftwork, time factors, etc.).

This model illustrates the range of methodological constraints that exist in shiftwork research. We will try to discuss some of these constraints and some of the ways in which we tried to overcome them in our studies.

Issues and Problems of Generalizability and Comparability of Shiftwork Research in Different Countries

One precondition for generalizations derived from shiftwork research, and for comparability of results between countries, would be a sound statistical documentation of the amount of shiftwork and of the trend of development of shiftwork in different countries. The first problem in this area is the definition of shiftwork. What kinds of shiftwork should be included? Some statistics include nightwork, Sunday work, and "work at unusual times". How many types of shift systems should be differentiated? Some statistics distinguish between 2 shifts, 3 shifts, and 4 or more shifts, and subdivide the shift systems with 3 or more shifts into continuous and non-continuous shifts. What types of work should be included? Some statistics include social services, as well as industry, but obviously, it is harder to get accurate data about shiftwork in the former. We should try to get international standardization of such statistics. Some proposals are made by Rutenfranz, Colquhoun, Knauth, and Ghata (1977b) to this end.

There is also the question of the trend of growth in shiftwork. Many people state that shiftwork is expanding, but clear-cut data for such statements are rare. It would be useful to have a statistical basis at least to estimate this trend. One example is given in Figure 1, derived from a report by de Jong (1979), who used the Reports of the Netherlands Ministry of Social Affairs as his source. From this figure, it appears that, in the Netherlands, the incidence of shiftwork increased from about 7% in 1909 to about 20% in 1970. More statistical data of a similar kind should be obtained in different countries. In Austria, we sent out a questionnaire through the labor unions and found that 21.4% of the respondents worked on shifts (for men, the figure was 23.8% and for women 16.1%). In industry alone (where we got the most reliable data), 27.2% worked on shifts and for about half of these, this included night work (Brössler, Kundi, & Taratula, 1979).

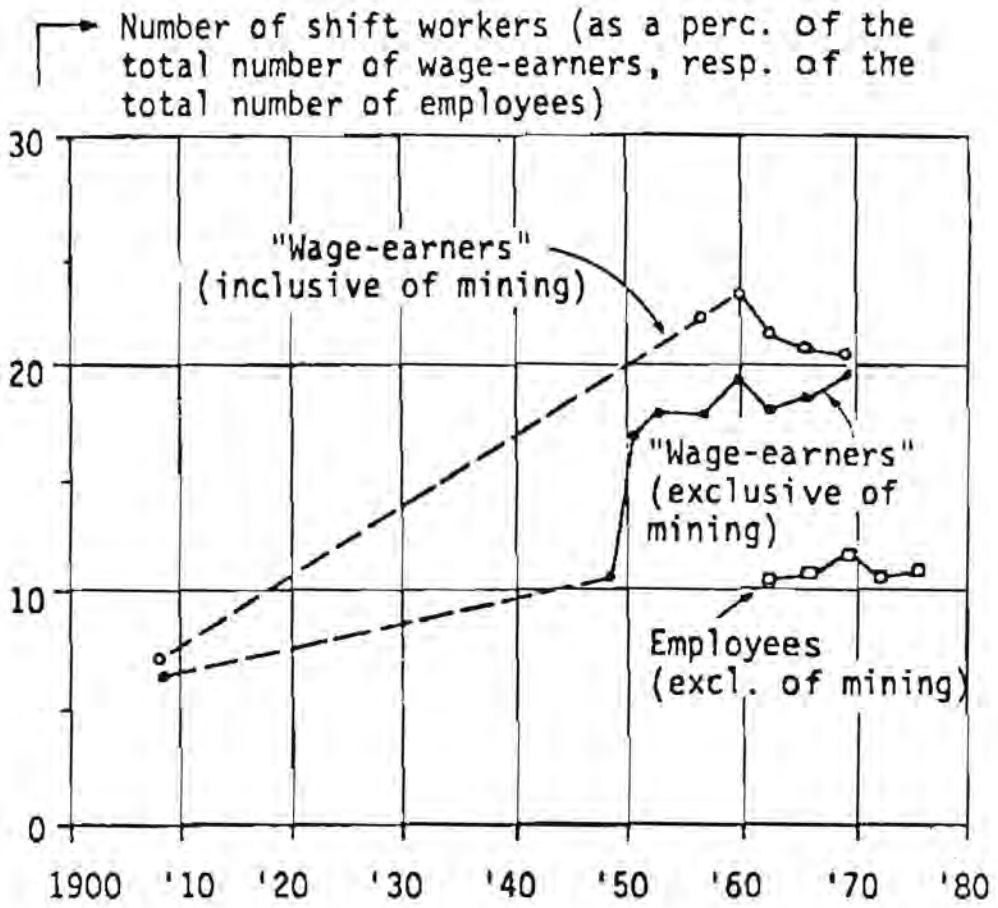

Figure 1. Changes in numbers of shiftworkers in industry (a) as a percentage of the total number of wage-earners, and (b) of the total number of employees (inclusive of wage-earners). Sources: Reports of Ministry of Social Affairs surveys, and relevant publications in Sociale Maandstatistiek (De Haan, Zeist, resp. Centraal Bureau voor de Statistiek). From: J.F. de Jong, Annex 5 in Haider and Koller (1979).

The comparability of shiftwork studies in different countries may be confounded by legislative, ethnic, cultural, or political differences. For instance, because of differing conditions, studies performed in some eastern countries often may not be acceptable to workers and managements in western countries, and vice versa. As an example of differences in legislation, it may be mentioned that in countries like Sweden, Netherlands, and some eastern countries, women are allowed to perform night work, whereas in Austria, France and Germany, this is forbidden. But even in these latter countries, women work in 2-shift systems, and in the services area, they often have to work at night. To be able to make general statements about shiftwork effects on women we would need more information on sex-dependent aspects, derived from comparable studies of male and female workers in the same job conditions.

Of course, these are many other factors which limit the generalizability of results from shiftwork research. Among these are age-dependent aspects, individual differences, motivational variables, differences due to task and job demands and so on. We will deal with some of these factors in the following sections.

Issues and Problems of Research Designs

In contrast to the "ideal" experiment described in the introduction, our research designs have to deal with highly selected populations. We will discuss some of the constraints resulting from these problems first for field, and then for laboratory studies.

Field Studies

Since, in most countries, we do not have detailed statistical data on shiftworkers, it is clearly impossible to draw "representative samples" of shiftworkers and control groups. But even if we had the statistical basis for it, such a procedure would be very difficult indeed. Most studies, therefore, have taken the workers in a particular factory as their "population". Such groups of workers are already selected at entry for different social, economic and personal reasons. Workers who think of themselves as being able to endure shiftwork will be overrepresented among the applicants. The initial medical examination will exaggerate this, since only those people whom the physician thinks will be able to endure shiftwork will be accepted for it. Moreover, as has been pointed out (Reid, 1957), each population of workers is a "survivor population", since those people who have changed work, or have retired early or have died have been "lost". This loss may be especially marked in shiftworkers who, for instance, may change their work for health conservation reasons.

The selection factors described above may be one reason why some studies (especially the earlier ones) have not found any differences in health between shift- and dayworkers (e.g., Wade, 1955). One way to partially control for the selection bias is to include a study of the "drop-outs" as an extra group. We have done this in our studies and have found some differences in health in this group (Koller, Kundi, & Cervinka, 1978; Kundi, Koller, Cervinka,& Haider, 1979; see also Andersen, 1960; Taylor, Pocock, & Sergean, 1972; Rutenfranz & Colquhoun, 1978). But it must be acknowledged that some studies with separated groups of drop-outs did not find differences between shift- and daywork-

ers with respect to mortality and absenteeism rates (Thiis-Evensen, 1958; Taylor & Pocock, 1972). The inconsistency in these results may, apart from selection factors, arise from the use of different kinds of "health" or "sickness" score. This will be brought up later under the problem of measurement and data collection.

Laboratory Studies

In laboratory studies, we are mostly dealing with small groups of young and healthy subjects. This may render it rather difficult to generalize the results to the "real problems" of shiftworkers. There are many issues connected with this question of real problems and their relation to laboratory studies on shiftwork. For instance, reentrainment of physiological functions may be quite different under laboratory and field conditions. Motivation also may be different, since laboratory studies hardly have "real consequences". Again, in sleep studies, there are discrepancies between field and laboratory situations because, in the latter, the subjects can take compensatory sleep after the experiment whereas shiftworkers cannot. One might question, therefore, whether laboratory studies are useful in shiftwork research at all. This question was discussed at length in our European Seminar on "Performance time functions" (Haider & Koller, 1979), in which it was agreed that there are many ways of bridging field and laboratory studies. Some of them will be mentioned here.

How to Bridge Laboratory and Field Studies

One conclusion of the European Seminar was that field and laboratory studies do not constitute a clearly distinguishable dichotomy, and it seems better to think of any study as lying on a continuum, representing the amount of intervention and control that is exercisable. Therefore, both kinds of studies should be run in parallel, the laboratory studies affording more opportunity to control variables in testing specific hypotheses.

Field studies may be used to derive some of the hypotheses which could then be tested in the laboratory. Sleep studies may first be performed in the homes of the workers. Experimental studies would then follow in which the subjects would be awakened on a schedule similar to the one observed in real life. Further experimental shiftwork studies could examine the effects of combining shiftwork with other stressors like heat and noise. One experimental study (Rutenfranz & Knauth, 1972) suggested that sleep disturbances due to changed biorhythms and to noise may be additive, and one field study (Koller et al., 1978) showed that "drop-outs", even after years of daywork, still had more sleep disturbances due to noise than permanent dayworkers.

Field studies may also be used to confirm the results of laboratory findings under field conditions. An example of this methodological procedure is provided by the studies of Colquhoun, Paine, and Fort (1978), testing circadian rhythms of body temperature in a series of experimental studies under various types of watchkeeping systems, and then under field conditions during a prolonged submarine voyage.

Issues and Problems of Measurement and Data Collection

Since, as in other fields, the mere act of observation and measurement may influence the variables we want to measure, it is desirable in shiftwork research to use procedures available which are as unobtrusive as possible. Fortunately, recent technical developments have enabled some originally laboratory-bound measurement procedures to be adapted to the field situation. These are already available for many physiological measures, and such procedures will no doubt be developed in the future for performance measurements also.

Physiological Measurements and the Issue of Activation

Each physiological measure has its own methodological difficulties which cannot be discussed here in any detail. In shiftwork research, long-term recording over days or even weeks presents many technical problems.

For continuous heart rate recording, Rutenfranz, Seliger, Andersen, Ilmarinen, Floring, Rutenfranz, and Klimmer (1977a) give some criteria against which measurement systems can be evaluated. These criteria are:

1. Weight and size should be socially acceptable;
2. Uninterrupted use (>8h or, better, >24h) should be possible;
3. No constraints on subject mobility or on occupational and leisure activities (except swimming);
4. Sequential recording of mean rate over short time intervals (mins);
5. Data recovery unbound to "real" time;
6. No specific computing system necessary for data analysis.

Rutenfranz et al. (1977a) argue that telemetric systems do not fully guarantee points 2 and 3, and that the "cardiac interbeat interval distribution" technique does not fulfill criterion 4. On the other hand, these techniques may be better in fulfilling point 1 than the cardiocorder-techniques which actually fulfill all 6 criteria. There are now different cardiocorder systems available (like Mnemoport "Helligre", Medilog "Oxford", Meditype "Siemens", etc.) which may also be judged against criteria like the possibility of analyzing the form of the ECG, how precisely one needs the heart rate to be recorded, and so on.

Since body temperature is one of the parameters most frequently examined in shiftwork research,one should also evaluate the increasing number of available transportable systems for continuous measurement of this variable. The Thermolog system, for instance, uses a solid state memory instead of tape recording for long-term monitoring of both body temperature and activity. Some newer developments aim at picking up deep body temperature from the skin surface (see Fox, Solman, Isaacs, Fry, & McDonald, 1973). It is important to evaluate the reliability and validity of such methods for shiftwork research.

Besides heart rate and body temperature, the other measures most often used in shiftwork research are respiratory rate, EEG, and certain hormone levels (e.g., adrenalin and melatonin). The state of the organism defined by some of these variables is, in many cases, characterized as its level of "acttivation". But we must be quite clear that "activation" is not a single dimension defined absolutely by the covariation and functional relationships of the above named physiological parameters. In neuro- and psychophysiology, we pre-

fer to think of a "hierarchical system of activation" (Haider, 1969, 1970), as shown in Figure 2.

In this hierarchical system, we first assume some basic, general activation or arousal mechanisms, normally involved in regulating wakefulness and sleep. Then we have "tonic" activation with long latencies and durations, slowly changing the state of the organism between low and high arousal; reticular and limbic activation mechanisms mediate these changes. Next there are "phasic" activation or arousal mechanisms with shorter latencies and durations; the truncothalamic and mediothalamic-frontocortical systems may be involved in these mechanisms. Finally, we have to consider highly differentiated and selective activation processes, related to selective perceptual, cognitive, and motor acts without gross changes in arousal level; specific thalamocortical and striatocortical feedback mechanisms may be responsible for these processes.

Empirically, the generality of activation may be defined operationally by the number of variables differentiating different levels. The greater the number of indicators that vary as the level changes, the more general is the activation. This is shown for some physiological variables in Figure 3.

Models like this may perhaps be helpful in solving problems such as the choice of physiological variables in shiftwork research. For instance, the question arises as to what kind of information you may expect from each variable. If you want information about basic changes of general activation (for instance in circadian rhythms over long times), then the variables at the right hand of Figure 3 seem to be the most appropriate, i.e., body temperature and hormone levels will probably give good results for this purpose. If, on the other hand, you want information about shorter cycles (phasic activiation changes), then pulse rate and EEG will be appropriate; the EEG has proved its special usefulness for changes in sleep rhythms, sleep cycles, and so on: from the study of slow (DC) changes, we know that these vary with sleep-wakefulness cycles (Caspers, 1961, 1963) as well as with more specific phasic changes like expectancy and motor readiness. [As an aside here, it would be interesting to see what changes occur in these slow brain potentials during the adaptation of different circadian rhythms to an altered regime.] Since in a hierarchical system each level influences the other levels to a certain degree, it would be interesting to discuss the question of desynchronization in the light of such a system, in which each variable has to be conceptualized as a separate but related organismic function.

Performance Measurements

In field studies, performance criteria are, in many cases, relatively easy to collect. There are, for instance, data on work output, occurrences of errors, frequencies of accidents and so on. But, with certain exceptions, it has not yet been shown that such data are very informative for shiftwork comparisons. Most results are masked by stronger relationships, and dependencies on factors like motivation, working strategies, contact with the research team, amount of intervention, etc. Since most workers are able to maintain a given output level within certain limits, it is probably more informative to look at what "costs" an individual incurs in maintaining a certain performance level than just to measure performance alone. One should also look at the relationship between performance and expectations of work demands.

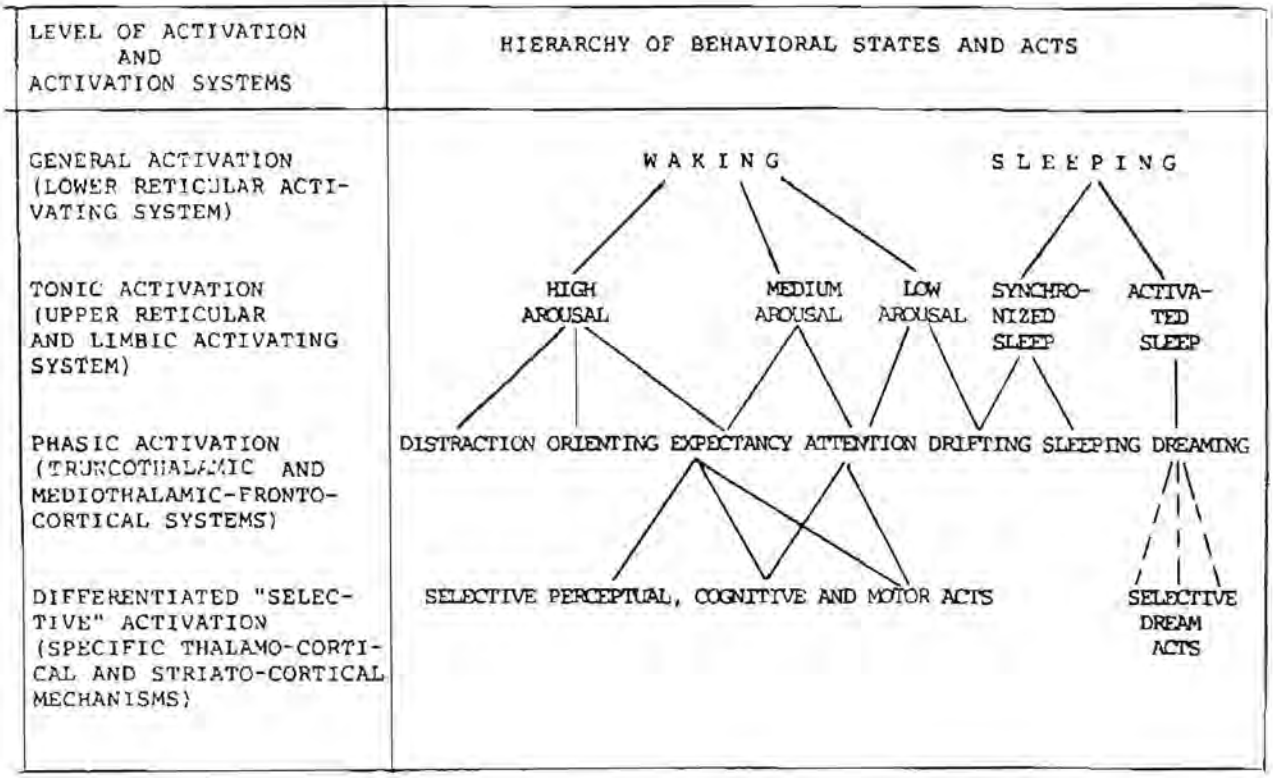

Figure 2. A hierarchical model of activation and behavior.

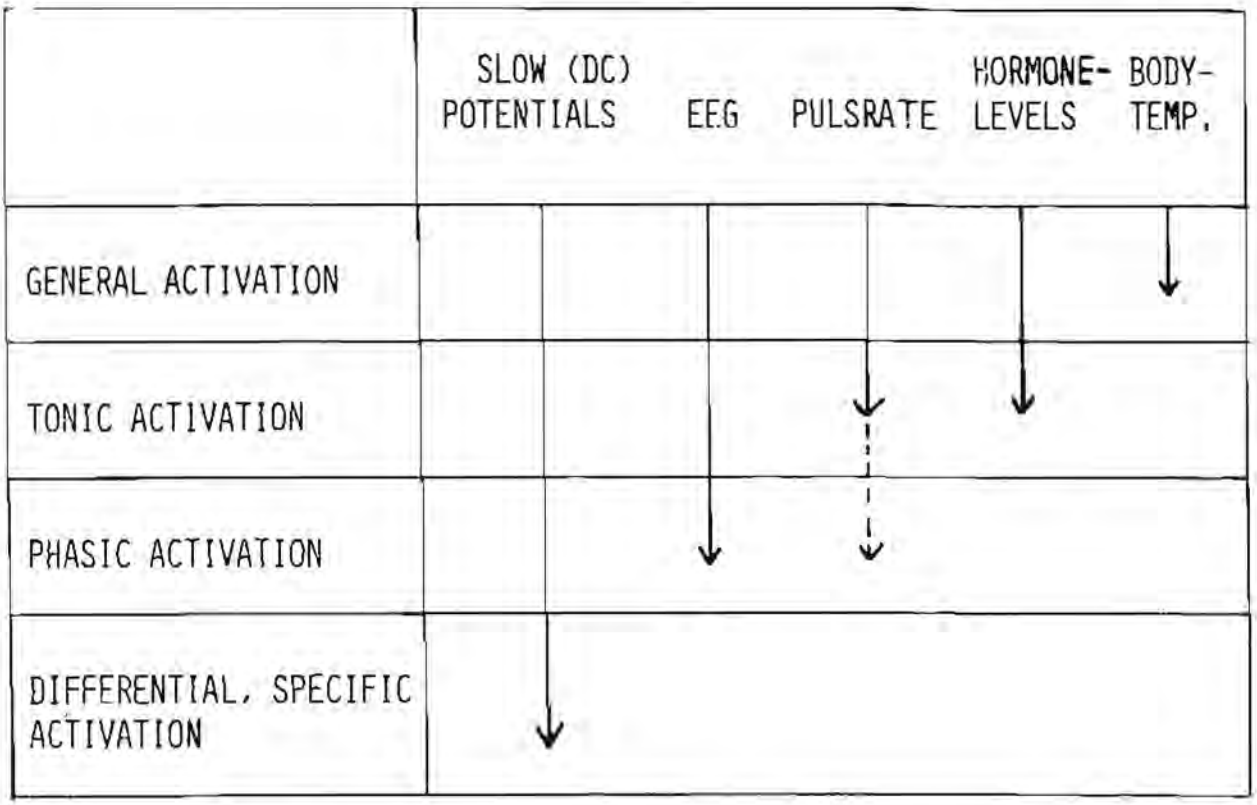

Figure 3. Different levels of activation an their relation to physiological variables.

Many performance tasks have been shown to exhibit circadian variation (see for instance Colquhoun et al., 1975; Rutenfranz and Colquhoun, 1978), but others have not. One of the methodological difficulties here may be that most tasks are developed for specific investigations, and that no satisfactory categorization of performance tasks exists. One of the proposals in the "European Seminar" (Haider & Koller, 1979) was, therefore, to try to develop some kind of "taxonomy" for performance by relation both to different tasks as well as to different situations, and to try to establish "phase maps" of mental performance, sensorimotor performance, and other performance data and to examine their relation to phase maps of biological rhythms. A further suggestion was that more attention should be paid to individual differences and subgroups in performance, to determine if they are consistent, and also if they are predictable. In this connection, one should try to find out why the results of circadian rhythm performance studies are only valid for some people in some situations for some tasks.

Many performance (and other) measures have circadian rhythms which differ in period, amplitude or phase. It has been shown, for instance, that speed and accuracy measures may represent different diurnal components of performance (Englund, 1979), and that immediate memory decreases over the normal waking day, whereas delayed retention is superior for material presented in the afternoon or evening (Folkard, 1979). In view of these complexities, special methodologies will be needed to analyze basic changes in overall behavior, as well as in phase shifting, adaptation, and reentrainment; the currently favored cosinor approach may not be sufficient for these purposes. A promising new technique, based on likelihood ratios, has been devised by Monk (1977).

For further development in the field of performance measurement, we will have to tackle a lot of important unsolved problems. One of these is the identification of performance measures which can be used both in the laboratory and in the field. Another one is the development of reliable techniques to measure an individual's level of motivation, as well as the degree of effort he applies in performing a task.

Questionnaires and Subjective Indices

Personality differences, assessed by specially devised questionnaires, have been shown to be important in shiftwork research. Blake (1967), for instance, observed differences in the temperature rhythm of introverts and extraverts. Colquhoun and Folkard (1978) showed that these differences were more marked in neurotic subjects and that "neurotic extraverts" exhibited the greatest degree of adjustment of their temperature rhythm to night shift. In other research (Horne & Östberg, 1976; Torsvall & Åkerstedt, 1979) questionnaires to determine diurnal types have been devised. The reliability of such instruments is quite good. For instance, Torsvall and Åkerstedt (1979), found a correlation of 0.79 between two administrations in a one-year interval. Some authors (Östberg & Svensson, 1975; Breithaupt, Hildebrandt, Dohre, Josch, Sieber, & Werner, 1978) have shown that "morning types" react more adversely to night work than "evening types".

Each typology has, of course, many methodological problems. One problem is that definite "types", defined as extreme at one or the other end of the scale, are rather rare. Another problem is that, at the moment, the correlation between different circadian-type questionnaires seems to be rather low.

Finally, there is lack of agreement about the correspondance between different typologies. Hauke, Kittler, and Moog (1979), for instance, were not able to confirm the suggestion of Colquhoun and Folkard (1978) that "evening types" may correspond to "neurotic extraverts".

The reason for introducing such concepts as Introversion-Extraversion and Morning-Evening types into shiftwork research is, of course, to find out if there are attributes of the worker which make him more or less adaptable to shiftwork. However, little or nothing is known about the stability of attributes over time; this introduces a further methodological problem into research on the prediction of adaptation to shiftwork, which has been considered by Tasto, Colligan, Skjei, and Polly (1978).

Many questionnaires and subjective indices are available from which a researcher can choose those which seem to be most relevant for his study. Of course, the "ideal research design" which we mentioned in the introduction would require measuring instruments for all the variables relevant to shiftwork. But this is obviously utopian. In our study, we based our questionnaires and interview forms partly on validated and tested procedures (Mott, Mann, McLoughlin, & Warwick, 1965; Neuberger, 1976; Östberg, 1973; Rutenfranz, Knauth, Hildebrandt, & Rohmert, 1974) and partly on techniques developed by authors (Koller et al., 1978). The headings for the different groups of questions asked are listed in Table 1.

Table 1

Headings of Question Groups

Questionnaire Items
1. Personal and Family Data
2. Details of housing, with special respect to sleeping conditions
3. Job History
4. Attitudes towards various elements of shift systems
5. Opinion of different working conditions
6. Stress-producing factors at work place
7. Family Life
8. Leisure time activities
Interview Items
a. Attitudes towards materialistic and idealistic values
b. Morning-evening-type assessment
c. Biorhythmic functions assessment
d. Sleep-quality assessment
e. Health state: subjective assessment, psychosomatic disorders, disorders of several functional systems
f. Eating and smoking habits, alcohol and coffee intake

We cannot avoid having to rely on subjective scales, especially in the case of "measurement" of attitudes. One problem in using such scales is how to estimate standard indices, like reliability. It may well be that "one-item

scales" turn out to be superior to collections of specially chosen items because, in these cases, homogeneity of the item set is a necessary condition for the sum score to be meaningful and homogeneity is very difficult in most scales used in shiftwork research.

A further basic problem in using questionnaires and subjective scales is that the score obtained from them may represent, to some extent, stereotyped responses; thus we cannot be sure that they correspond to real feelings, even subjective ones. Shiftworkers' answers to questions about their life and work are influenced by many personal, situational, and social factors (Nachreiner, 1975). One of these is the fact that most field studies cannot be performed "blind".

The mere fact that shiftworkers know that one of the aims of the research is to study their work problems may bias their answers in one or the other direction. Thus, in some cases, they may tend to describe their situation as very strenuous and therefore particularly meriting compensation, financial or otherwise. But in others, they may try to avoid a kind of "cognitive dissonance" by describing a situation in which they stay on anyway as not too strenuous. Some results of our pilot study on "retired shiftworkers" support the latter hypothesis because these people's attitudes towards shiftwork are worse than active shiftworkers.

No general solutions for these problems exist as yet. It would seem that in this field, we will have to rely largely on "trial and error" to identify, and then to exclude scales which do not differentiate between different groups of shiftworkers, or between shiftworkers and dayworkers, etc.

Measurements of Health State and Wellbeing

To define health and wellbeing operationally is not an easy task. Some criteria, like "Absenteeism" are apparently obvious, and data can be collected relatively easily; but it is difficult to determine the extent to which personal attitudes and social and legislative influences are involved. In Austria, for instance, we have a very high proportion of 3-day absences, since for longer periods a medical certificate is needed. So it is small wonder that absenteeism data have not given clear-cut results in shiftwork research.

Another possibility is to use mortality and morbidity statistics in epidemiological surveys. Unfortunately, in most cases, we have no sound epidemiological methods available to perform well-controlled studies; furthermore, the results will depend very much on the way that the original data were collected, which varies widely between countries. In a number of countries (excluding England, Wales, Canada, Holland) there are, except for the initial medical check, no obligatory medical screenings for ordinary shiftworkers, so that no current register of "nonoccupational" diseases exists. Another point is that workers are not obligated to give complete details about their health state to the occupational health doctor. So medical examinations carried out by different industrial physicians may differ widely. Further, such data refer only to those complaints and symptoms reported during working hours, and to first-aid cases. For all the groups in our study, we used medical histories of diseases and disorders of different functional systems which were obtained and evaluated by the same physician.

Many of the procedures used to operationally define state of health, presence of disease, and wellbeing need further evaluation and, if possible, a certain degree of international standardization. One proposal would be to base scoring systems on the International Classification of Diseases.

Issues and Problems of Data Analysis and Modelling

Progress in science may be viewed as proceeding in stages of increasing knowledge from primitive models based on only relatively few facts to complex models that incorporate much detailed and well-established information. Wold (1973) makes a distinction between descriptive and explanatory knowledge and indicates two lines of evolution from low information to high information models. One line by-passes higher degrees of explanation, using the results from controlled, replicable experiments, and also nonexperimental evidence and various facts to derive explanatory information expressed in the form of descriptive information, for instance by factor analysis or canonical correlations and then again uses experimental and nonexperimental data and known facts, to build a complex model. The final models emerging from both lines of evolution will contain much information of both an explanatory and of a descriptive nature. They are complex structures that have considerable explanatory power and also provide much descriptive knowledge via their many parameters. In the following sections, we will discuss some ways of constructing such complex models for the mechanisms of shiftwork effects and for their dynamic, sequential development.

The Complex Interaction Structure of Shiftwork Effects

As examples of complex model building for shiftwork effects on health and wellbeing, we will discuss the Swedish model of Åkerstedt, Fröberg, Levi, Torsvall, and Zamore (1977) and that of our own group (Kundi et al., 1979). The model which the Swedish group uses to illustrate the mechanisms behind the consequences of shiftwork is shown in Figure 4.

The starting points for the discussion are the circadian rhythms of physiological and psychological functions as reviewed by Colquhoun (1971,1972) and Fröberg (1975). The normal daily rhythm of an individual alters in response to his particular working hours. If the new daily rhythm changes in a way which adjusts it to night work, it then comes into conflict with the daily rhythms of family and society, and this may lead to difficulties in fulfilling social roles. But if the new physiological and psychological rhythms do not become sufficiently adapted to nighttime activity and daytime sleeping, conflicts result with working-hour requirements. These eventually cause different types and degrees of complaints, such as tiredness, difficulty in sleeping, digestive problems, etc., which together lead to a gradual development of poor attitudes to shiftwork, absenteeism, and possibly actual illness.

The results from certain controlled experiments and field studies provide an explanation of some of the ways in which shiftwork can, in the long run, result in reduced wellbeing and increased health complaints. For instance, the demonstration that during a working period of 72 hours, circadian rhythms in adrenalin and melatonin secretion, body temperature, self-rated fatigue, and performance capacity are clearly evident (Fröberg, Karlsson, Levi, & Lidberg, 1975), with high activation in the middle of the day and low

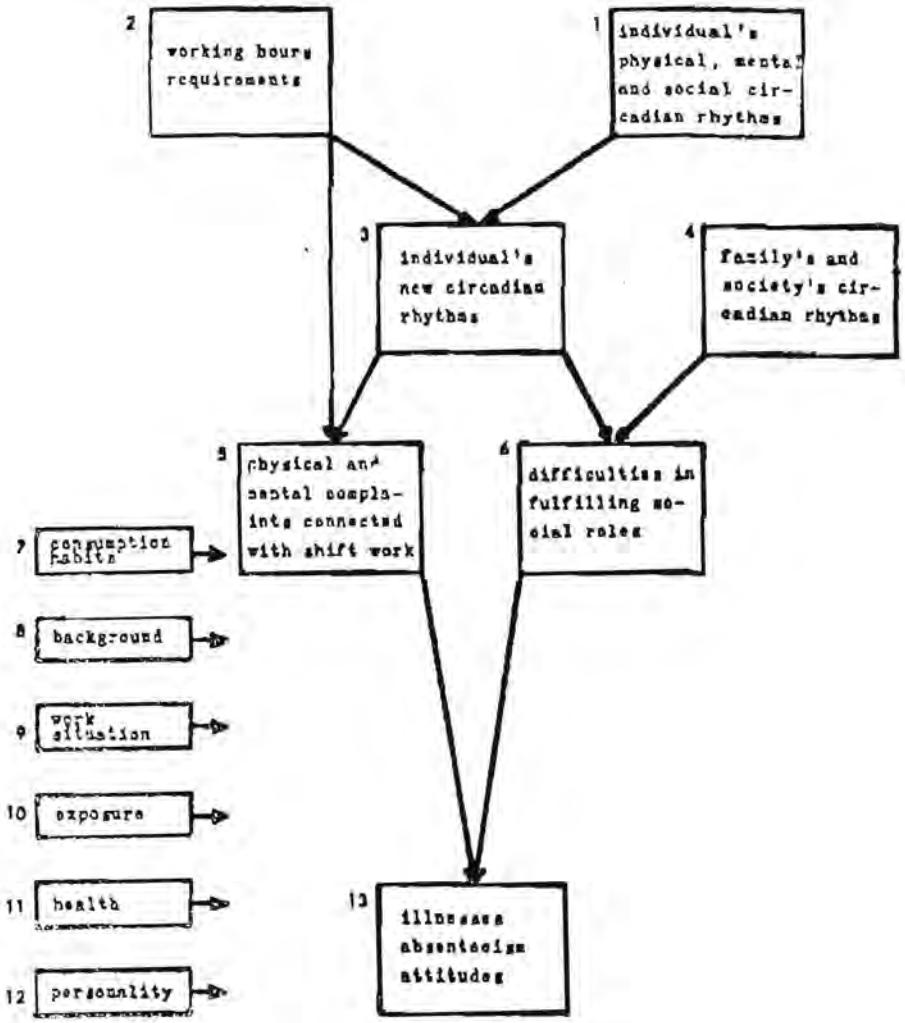

Figure 4. Model of the mechanisms behind the consequences of shiftwork (From: Akerstedt et al., 1977).

activation in the middle of the night, means that during the night shift, a worker must be active when his psychophysiological functions are not in an appropriate state. This may lead to a drop in performance capacity (as, for instance, has been shown by the increase in the number of emergency stops made by engine drivers at night: see Hildebrandt, Rohmert, & Rutenfranz, 1974, 1975). Sleep-deprivation studies have shown that it may be as bad to work at night as it is to work in the daytime without having slept at all the previous night. And Johnson and MacLeod (1973) found that performance capacity and wellbeing were still considerably reduced when sleep was allowed, if it was limited to approximately 5 hours only.

Besides the difficulties resulting from conflicts between physiological and psychological daily rhythms and working-hour requirements, the model takes into account the difficulties resulting from conflicts between the new social rhythm of shiftworkers and those of the family and society. Shiftworkers are excluded from a great deal of community life and may thus be placed in a kind of "stress" situation through social role conflicts. Although it has been pointed out that such conflicts may lead to psychosomatic disorders (Mott et al., 1965), their effect on the health of shiftworkers has not been investigated in detail.

The model also indicates that the whole process is modified by a number of variables. These include consumption habits: smoking, coffee intake, and meal timing; demographic factors: age, sex, marital status, dwelling conditions, children; exposure: frequency of night shifts, full- or part-time experience of night work, etc.; health state; personality factors: neuroticism, extraversion. Finally, the authors state explicitly that the model has been radically simplified, and that interactions between the variables are not included.

Our own model (Kundi et al., 1979) may be used to demonstrate the second line of evolution of complex models. We started by computing canonical correlations between groups of relevant variables. For this purpose, categorical data were transformed (McCall method) and qualitative information was coded on arbitrary scales. The discussion of possible mechanisms can begin with a description of the resulting network of relationships between variable groups. This network is shown in Figure 5.

The variable group "health state" is correlated significantly with most other variable groups. It shows two significant canonical correlations with the variable group "work strain". The first one indicated an interaction between mental work load and digestive disorders. The second one indicates a relation between the fear of not being able to continue to bear the work load until retirement and feelings of tiredness or exhaustion. "Family life" also shows two significant correlations with health state. The first one reflects a relation between difficulties in fulfilling the expected social role within the family and psychosomatic symptoms. Among the risk factors, smoking, and the tendency to change eating habits under stress, are particularly related to health state. Sleep problems are related to family problems, and both are correlated with job satisfaction and attitudes towards shiftwork, which in turn are both correlated with health state.

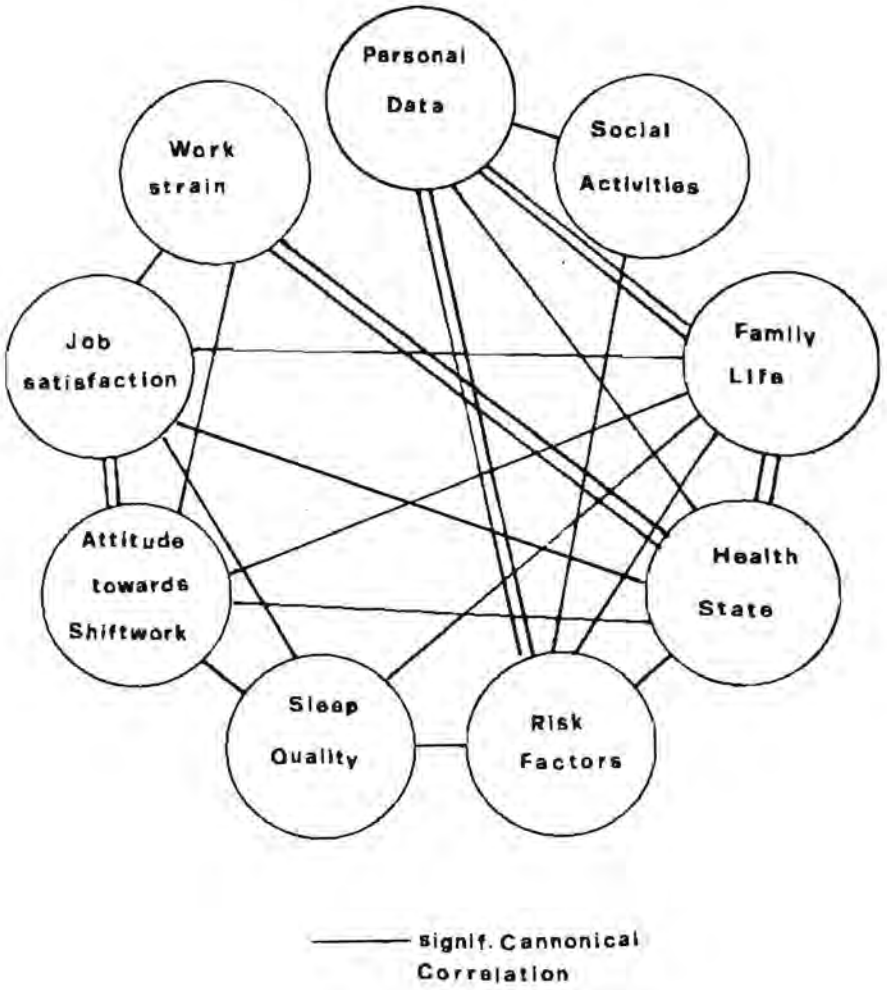

Figure 5. A network of relations between 9 "variable groups" in shift-workers.

If we now start to build a model for the complex interaction structure of shiftwork effects on this descriptive information, it must be made clear that this model is mainly hypothetical though it is based on our empirical findings and other experimental and nonexperimental data as well as on known facts. The model is illustrated in Figure 6.

In this model, we assume that family life, sleeping behavior and attitudes towards shiftwork are central in the process of adaptation for shiftworkers. Obviously, shiftwork alters the daily rhythms (as described earlier in the discussion of the Swedish model). This results in a reduction in sleep quality (as shown by Rutenfranz & Knauth, 1972). Sleep problems may affect health and wellbeing, but may also lead to reduced contacts within the family. If the shiftworker tries to improve family relationships by increasing his contact time, this may leave him with less time for sleep. Furthermore, difficulties with sleep and with family relationships are likely to result in increasingly negative attitudes towards shiftwork, and in more job conflicts, both of which may in turn lead to reduced sleep quality. This complex of feedback mechanisms may interact directly with wellbeing and health, or it may work indirectly through an increase in risk factors like nicotine and coffee consumption. The whole process is differentially modified by personality factors, as well as by characteristics of the work situation and the social environment.

Empirical tests of many of the components of this model, as well as the Swedish model described earlier, are at present, still lacking. Because of the many constraints described above, these tests are very difficult to perform; Thus, their absence should not be attributed solely to laziness on the part of the respective authors of the models.

The Dynamic Structure of Time-Contingent Shiftwork Effects

One of the major methodological problem areas in shiftwork research arises from the fact that it involves many time contingencies. On the one hand, there are the circadian rhythms already described. On the other hand, there are the long term variables of age and exposure to shiftwork. If shiftworking increases the probability of complaints, one should find a deterioration in health as the amount of shiftwork increases. This does appear to be the case in some studies, including our own. This deterioration, however, could be simply an effect of age, because amount of shift experience and age are positively correlated. However, Figure 7 shows that the reduction in "health score" with age is more pronounced in shiftworkers than in day workers, and that the difference is especially pronounced in older workers.

Similar results have been found by other authors. Aanonsen (1964) and Åkerstedt et al. (1977) noted that older people slept less and that their sleep was inferior when they were on night shift. One interpretation of this was that the effort involved in switching between day and night work may start to become intolerable at the age of 45. Similarly, Wever (1974) observed that with increasing age, the time taken for circadian rhythms to adapt to shift changes becomes longer.

As mentioned in the introduction, in the ideal cases, we would have complex statistical procedures available for analyzing repeated measurements ob-

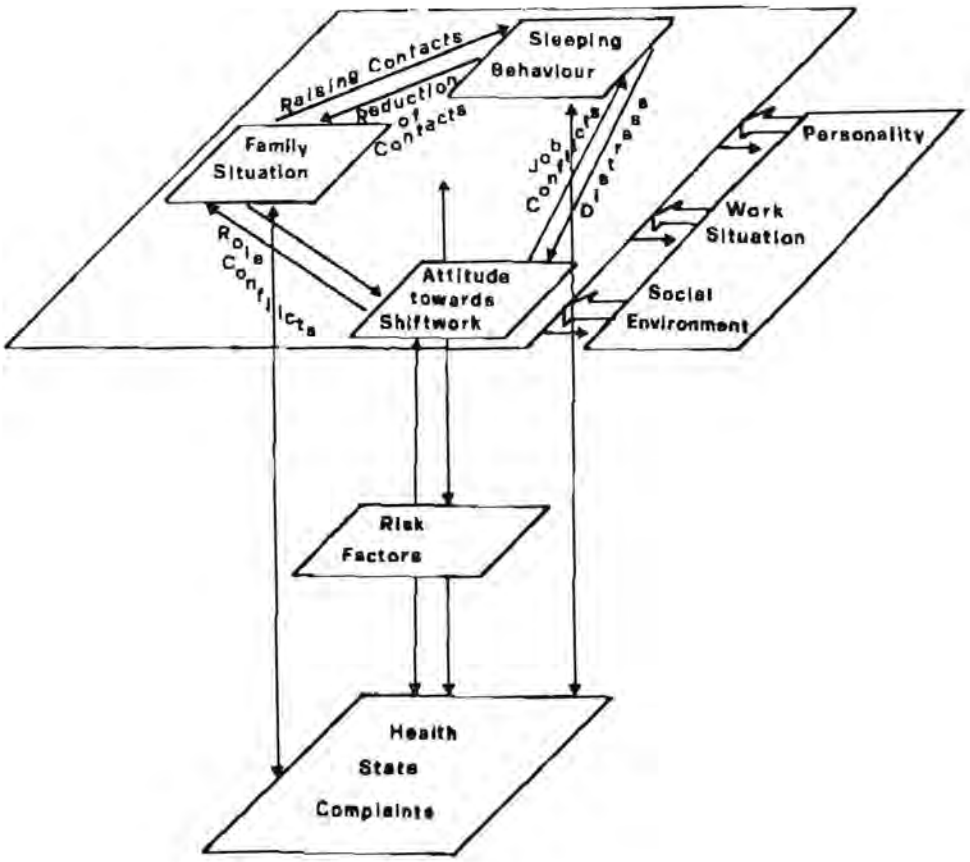

Figure 6. A model of the complex interaction structure of shiftwork effects.

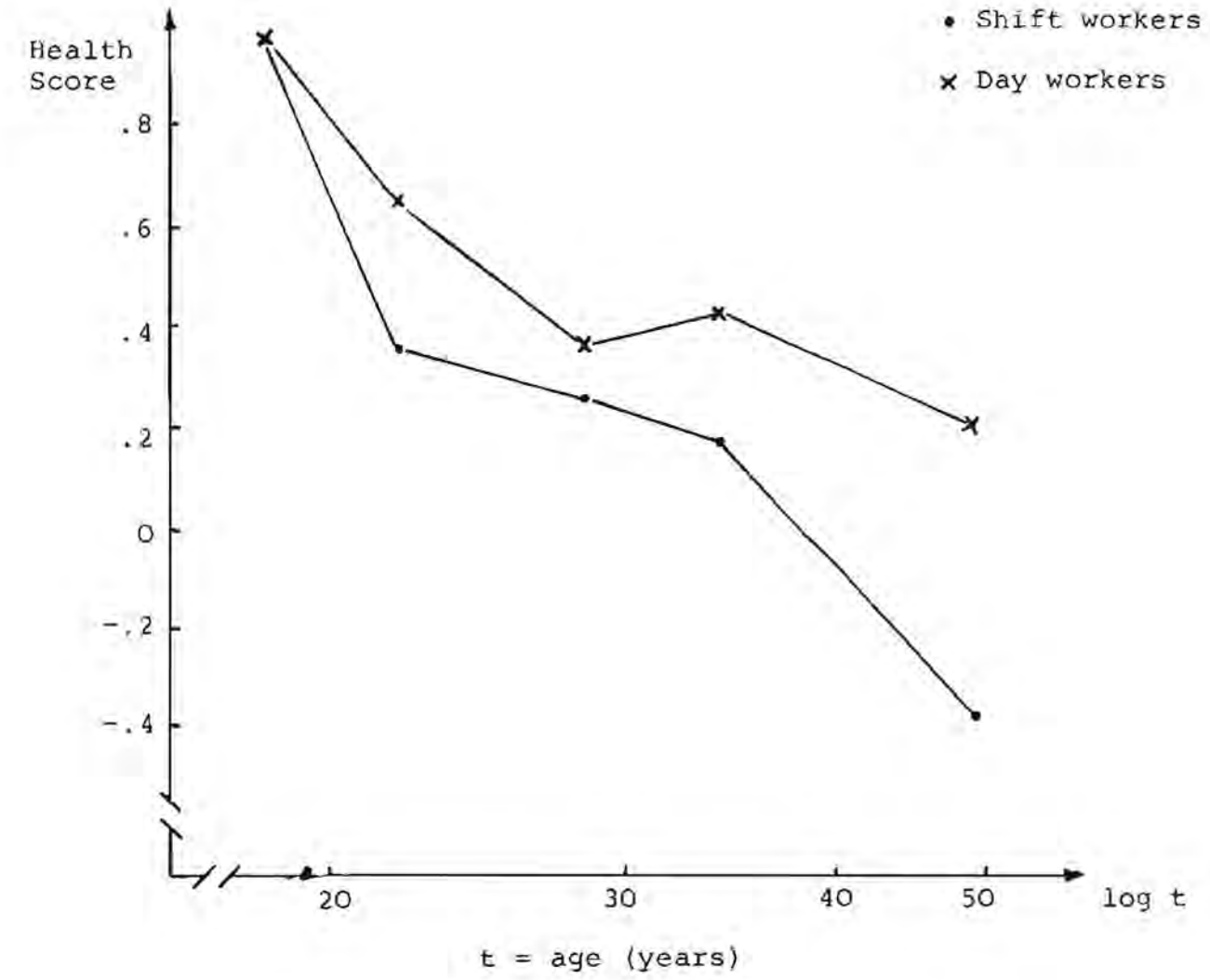

Figure 7. The deterioration of health with age in shiftworkers and dayworkers.

tained from many subjects in multifactorial designs that include time as a variable. In our study, we tried to analyze the dynamic properties of the relational structure described above by the use of Nonlinear Iterative Partial Least Squares (NIPALS) modelling (Wold, 1973). In a 3-step iterative process, we obtained weights for each variable group which characterized their power in predicting health state for different numbers of years on shift.

It was found that the different variable groups were not equally strongly related to health state and that these relationships were not stable over time. Figure 8 demonstrates these dynamic features of the relationships.

In the sequential development of interactions between health state and other variable groups, we may hypothesize different phases: In the first phase, which one might call the "Adaptation Phase", the main covariation is between sleeping behavior, work strain, social activities, and health state. In the second phase, which one might call the "Sensitization Phase", the variables 'attitudes towards shiftwork', 'job satisfaction', and 'family situation' become highly important. During this phase, the variables 'sleeping behavior', 'risk factors', and 'Morning-Evening Type' also start to increase in importance and, after between 23 and 40 years of work on shift, these 3 variables, together with attitudes towards shiftwork, have the greatest power in predicting health state, whereas all other variable groups drop in their importance. Figure 7 clearly shows this dichotomizing effect which characterizes the third phase or "Accumulation Phase".

One of the conclusions of this model is that there exist groups of variables like "job satisfaction', 'work strain', and 'family situation' which seem not so much directly related to the eventual reduction in health state, but rather act by making the shiftworker more susceptible ("sensitize him") to the "primary risk factors" of disease.

A "Destabilization Hypothesis" for Shiftwork Effects

In discussing mechanisms for shiftwork effects, it must be clearly remembered that many of the results of studies are conflicting, that a large proportion of the shiftworking population does not show an obvious reduction in health and wellbeing, and that many shiftworkers actually prefer shiftwork to other kinds of work. Therefore, we cannot expect to arrive at general causal explanations for shiftwork effects. We must assume rather that the whole process of such effects may, under certain conditions, lead to complaints and to reduced health state, but that it is also possible for this process to be stopped, for the feedback-mechanisms to be stabilized again, and for resultant adaptation of the worker to occur. This means that, methodologically, we should not look simply for causal chains between shiftwork on the one hand and health or wellbeing on the other, but rather try to establish the whole network of significant relations between the different parts of the process, and to then evaluate the conditions and possibilities for stabilization and destabilization of the complex interactional structure.

The interactional network obviously has dynamic features. We must, therefore, try to explore the time-contingent sequential development of the whole structure. Our data indicate that the processes of Adaptation, Sensitization, and Accumulation are important in this development. Some people are obviously

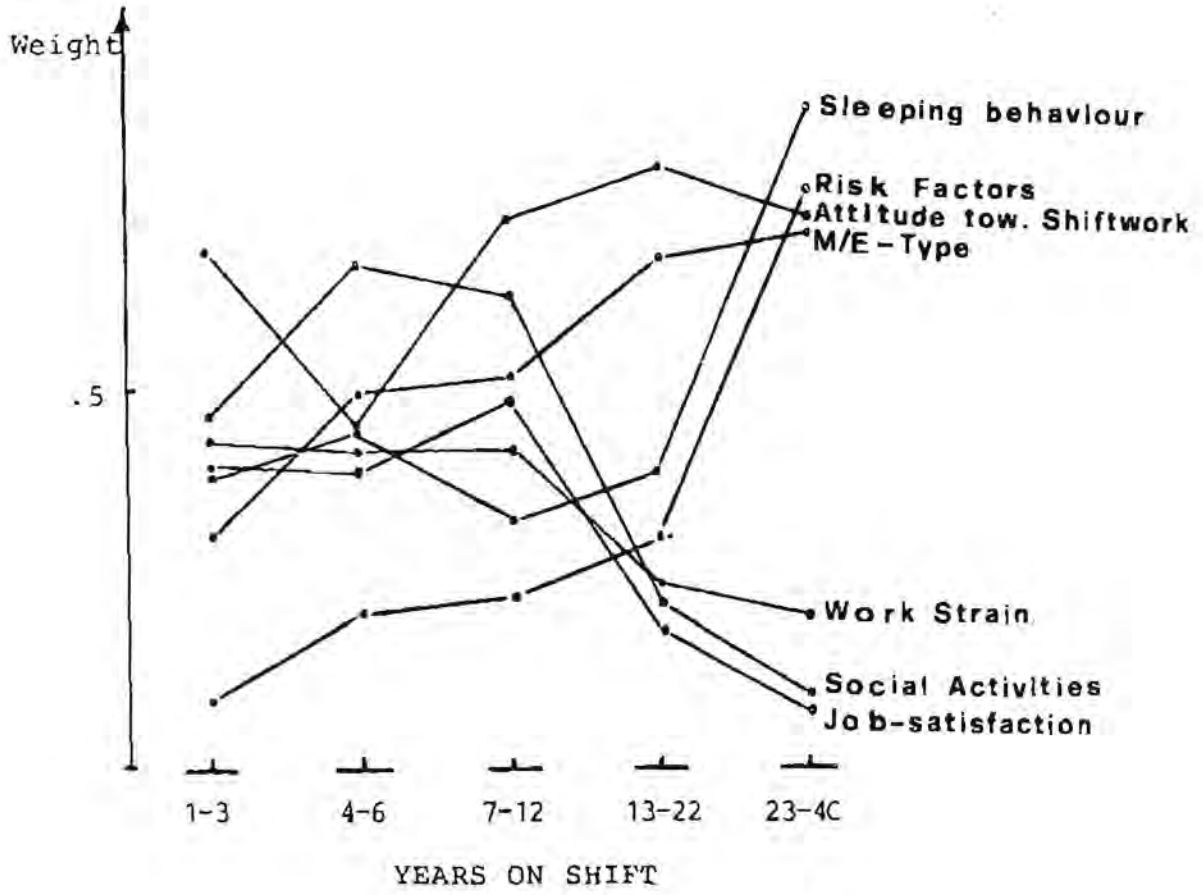

Figure 8. Weights for different variable groups, characterizing their power in predicting health state following different degrees of exposure to shiftwork (years on shift).

able to adapt to the problems of shiftwork and to stabilize their "person-environment relationship" at a new "steady state". Others may reach the Sensitization Phase, but fail to exhibit complaints and symptoms related to work strain. [But it should be noted that those people may still be sensitized for other risk factors: we have demonstrated that "drop-outs", even many years after quitting work, have higher sensitivity to noise than dayworkers; see Koller et al., 1978.]

A certain proportion of shiftworkers finally reach a stage in which complaints and symptoms accumulate, and the probability that they will have sleep problems or develop diseases of the gastrointestinal, circulatory and/or nervous system, increases. In this group, long exposure to shiftwork may then be associated with more sick leave and the "accumulated" complaints may eventually lead to absenteeism (Åkerstedt et al., 1977).

Methodologically, it must be pointed out that our data on time-contingent effects are based on a cross-sectional study of different groups of workers at each of a number of levels of shift experience. The idea that there are different phases of the complex dynamic structure can therefore only be proposed as a working hypothesis. Further studies of a longitudinal, prospective nature are clearly needed to confirm the hypothesis. But it seems to us that such a model of time-contingent sequential development of destabilization, with some variable groups as "sensitizers", could be tested on different kinds of health disturbances and diseases which are known to be related to chronic influences. This seems to be specially true for psychosomatic disease patterns, but conflicting views on the importance of "psychosocial influences" in the etiology of coronary heart disease may also be clarified by the use of such a model.

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