8 Computerized Manufacturing and Sensory Perception – New Demands on the Analysis of Work[1]

Fritz Böhle, Brigitte Milkau, Helmuth Rose

INTRODUCTION

This chapter introduces an approach which broadens the scope of sensory perception analysis and its significance for the work process. We discuss phenomena such as the individual's feeling for certain materials and the way workers allow themselves to be guided by the sound of certain machines. The concept of 'subjectifying action' is the central focus and will be explained in depth using the tasks performed by skilled workers in mechanical engineering industries. This chapter also deals with changes in work which occur in connection with the application of new technologies and which have received little systematic examination up to now. We also probe the causes of new forms of mental and nervous stress as well as factors which endanger the continued maintenance of workers' skills and qualifications.

THE LIMITS OF EXISTING CONCEPTS

The idea that the application of new technologies involves changes in sensory perception during the work process is generally accepted among social scientists. The changes come mainly from the increasing technological intervention in the relationship between workers and their work tasks on the one hand and production processes on the other. The element of technical mediation is by no means a new one, yet with the utilization of new technologies it is attaining new quantitative (more fields of application) and qualitative (data processing, progressive automation) dimensions. Existing work analysis concepts, however, are inadequate for grasping, let alone assessing, the resulting changes occurring in sensory perception. To date, the sensorial components involved in the work process have only been considered in terms of their implications for imposing physical strain on the individual (noise, heat, demands made on physical

endurance). When sensory perception is seen in connection with its effect on the work process, then concepts come to the fore which are primarily oriented to the cognitive, rational model of receiving and processing information. A characteristic of this model is that without cognitive, rational interpretation, whatever is perceived sensorially remains at the level of simple, physiological 'stimulus-response processes' and more or less automatic motor sequences. This is particularly evident in the category of 'sensory motor skills'. The 'theory of action regulation' (Hacker, Volpert) places this category at the lowest level of action regulation that is shaped and controlled by cognitive, rational processes. Without rational thought, action takes place purely on the basis of primary physiological and mechanical processes or the remnants of what used to be governed by cognitive, rational processes (habitualization).[2] Such an interpretation is in keeping with the theories of sensory perception developed and accepted in general (psychological and physiological) research on perception, particularly since the turn around to the domination of cognitive psychology has taken place.[3] With this approach, however, the tendency is to greatly belittle the practical significance of sensory perception for actions and to describe it in biased terms.

If one examines actual work actions, one runs into a number of phenomena that are difficult to fit into the currently accepted analysis of sensory perception. Examples of this are, for instance, the frequently mentioned 'feeling for the material' or such work practices as being guided by the sound of a machine during its monitoring and inspection. Similarly, there are reports of skilled workers engaged in the monitoring of highly automated facilities having (or indeed requiring) a 'sixth sense' that anticipates what the instruments are going to indicate or do not indicate at all. Important decisions are often made – particularly by skilled workers – on the basis of feelings, without rational grounds.

Another example is 'technical sensitivity',[4] a category with a firm tradition in industrial sociology. More recent discussions refer to skills of this type in such terms as 'tacit skills' and 'empirical knowledge' (Wood 1986; Polanyi 1985; Malsch 1987). However, here too, one finds only a rather vague reference without a precise explanation of what is really meant.[5]

In view of the increasing utilization of computer-based information, control and communication technologies, it is becoming increasingly relevant to subject such phenomena within the work process to a systematic analysis especially since these phenomena seem to be affected by changes in the work process that are currently emerging. Moreover, they play an important part in debates about the differences between man and the computer and about the limits of artificial intelligence.[6]

In the following, we shall present our findings on this topic. Our studies

are aimed at broadening the analysis of sensory perception. This means that sensory perception is not viewed in isolation but in its relations with other components of work-related actions.[7] Within the framework of industrial sociological research there are connections to research approaches in which 'subjectivity' is discussed as a constitutive factor in the human capacity for work. Within the framework of research into the psychology and science of work there are links to approaches aimed at a 'contrastive analysis of work'.[8]

We shall proceed by describing some theoretical concepts for an extended analysis of sensory perception; then, we shall present the findings of our empirical studies and, finally, point out some consequences for further research.

SENSORY PERCEPTION AND SUBJECTIFYING ACTION

For our investigation it is expedient to distinguish between objectifying and subjectifying action. The category of 'objectifying action' refers to forms of action which – in correspondence with the predominant consensus – are performed according to rationally grounded action (see, for example, Habermas 1981). The basis for this form of action is a specific shaping of sensory perception, of the relationship to the (social and physical) environment and in the dealings with it, and the role played by feelings. It is characterized by a distance between the subject and the environment which is seen as being different from and independent of the subject doing the action. Moreover, there is the assumption that the environment displays generally valid, and in this sense, objectifiable characteristics and properties. To recognize these characteristics and properties and use them in practical action is the key aim of objectifying action. Thus sensory perception of this kind occurs based on the exact and reliable collection of (objective) information. Furthermore, it is a sensory perception which leads to a far more adequate understanding of the environment and appropriate forms of action if it is guided and interpreted by the intellect (comprehended, categorized, etc.). Knowledge that derives from scientific method and action based upon it are prototypical for such objectifying action (at least in theory). This coincides with the separation of sensory perception from subjective feeling. From this perspective, feelings are primarily an intra-psychic occurrence in the sense of individual states of experience (well-being/ill-being, happiness/unhappiness). They are thus wrapped in an aura of 'subjective introspection'.[9] Feelings either precede or succeed practical action; however, in the course of action itself they tend to 'disturb' and cause subjective distortions.[10] The predominant concepts of sensory

perception and the analysis of work are both oriented primarily towards objectifying action.

By contrast, the concept of 'subjectifying action' describes forms of action in which not only sensory perception, but also feelings, the relationship to the environment and the way one deals with it attain a different quality and significance in terms of practical action. Using the concept of 'subjectifying action', an attempt will be made to show the various components of an action, e.g. intuitive action, sensory perception, and associative and intuitive thought, in their interactive context as elements of specific forms of practical action. In doing so, we shall adopt findings from a wide range of interdisciplinary research and apply them to this analysis.[11]

We start with forms of sensory perception that can be described as a perceptiveness based on feelings and senses. The basis is a sort of participatory perception in which the subject experiences the environment not as something separate, but rather as a part or even an extension of himself. This is, for instance, like a hearing which 'listens to itself'. This use of the senses is commonly referred to as 'sensing' or 'feeling'. This sort of sensory perception does not take place in a fragmented and isolated way via individual sensory organs; it is all-embracing and is connected to the entire body.[12]

The basis for this kind of sensory perception is a relationship with the environment which can be termed 'sympathetic'. The subject doing the acting experiences the environment (things and people) not as unfamiliar, external objects, but as belonging to himself or herself; in the process of taking action they form a 'unity'. While in action the person seeks to synchronize his/her action with the environment. In this way, non-human things are made quasi 'human'. This does not mean that human qualities are projected onto them. The crux is that in performing an action, the subject identifies with characteristics and properties of the environment so that the person acting and the object being acted upon draw closer together and become more similar. In this sense, the environment becomes a subject.

Also characteristic of sensory perception are ways of acting in which the fundamental elements are empathy and subjective involvement in the sense of 'getting involved'. The mimetic, identificational reproduction of motions as well as dialogical ways of acting in which the subject neither influences nor reacts to his environment one-sidedly, but rather strives for a certain result through a process of mutual exchange, and 'shared endeavour' are vitally important. A constitutive element is the receptiveness to the possibilities inherent within and offered by both objects and persons which only come about or are developed by coming into contact with them. Action is therefore characterized by the union and simultaneousness of

action and reaction; the effects of one's own action are experienced directly and at the same time have the effect of directing action. Planned action is no hindrance to proceeding in such a way, provided enough space is left for the unity of active and reactive action.

Sensory perception and feeling cannot be separated in the ways of acting described here. The relationship of feeling to the object is fundamentally important. It is the medium in which the connection between subject and environment gets produced. In conjunction with sensory perception, feeling is an important factor in the recognition of properties and qualities in the environment as well as for the regulation of action. This kind of intuitive recognition has its counterpart in an intuitive, empathic way of thinking in which feeling, thinking and sensory perception are various aspects of the same process. Such intuitive recognition is based essentially on experiences which in this context should be understood as 'getting involved' and not merely as practice versus theory.

As described here, subjectifying and objectifying action are not hierarchically related, nor can they be reduced to nor substitute one another because each does something different. The fundamental point is the proposition that both subjectifying and objectifying action can focus on gaining knowledge about the environment which is relevant for action and on organizing that action in a suitable way.[13] The relevant insights and rules governing subjectifying action could be 'supra-individual' – that is, shared and effective at the collective level. What is crucial is that they are integrated into concrete actions and can only be experienced, imparted and learned in this way; they cannot be isolated and in this sense 'objectifying'.

We do not, therefore, consider it a correct scientific premise to attribute subjectifying action only to certain social areas, e.g. to the so-called cultural sphere or processes of interpersonal interaction and communication. Rather, it is our thesis that subjectifying action is indeed significant in the work process, particularly in dealing with things, i.e. work materials, tools and machines. Such a thesis cannot, of course, be grounded on only theories and concepts (although in this area, too, a number of further studies are both possible and necessary). Rather, an empirical base is also necessary. In our opinion, two things need to be accomplished in this area: first to demonstrate how the forms of sensory perception and ways of acting as defined by the concept of subjectifying action are essential aspects of practical work actions. Second – and this was our initial point of departure – it has to be shown that important changes in the work process after the introduction of information, communication and control technology can only be identified and analyzed when the concept of subjectifying action is adopted. In the following, we shall present examples of empirical findings which fulfil this twofold objective using a selected area of industrial production. The focus

will be on skilled workers' activities at conventional and CNC-machine tools in the mechanical engineering industry.[14]

AN EMPIRICAL ILLUSTRATION OF SUBJECTIFYING WORK-RELATED ACTION – SKILLED WORK AT CONVENTIONAL MACHINES

Taking the example of skilled workers' activities at conventional machines, we shall demonstrate that working practices such as going by the sound of a machine or the feeling for materials are based essentially on a subjectifying type of action.[15] In conventional manufacturing processes this kind of work action is an important part of the worker's skill and the way he does his work. The following section discusses the essential characteristics of work-related action.[16]

Sensory perception mainly takes place via several senses simultaneously, i.e. the eye, the ear, hand, and the body and movements of the body. Manual movements, such as turning a handle or mounting a workpiece are not isolated, individual manipulations that exist by themselves. Seeing and hearing, too, are directly connected to movements of the body which change angles and distances. If one takes a closer look at the use of the senses, it becomes clear that an important part is played by precisely the perception of those circumstances that cannot be identified and defined objectively, rationally and unambiguously. It is, for instance, imperative that skilled workers check and identify defects and disturbances using the sound of the machine and the various processing operations. What it is exactly that skilled workers hear and how they recognize whether 'everything is running smoothly' during operation, 'cannot be precisely described and measured', to quote one skilled worker. It is clear that 'feeling' plays a particularly important role. This becomes evident when workers describe how they can recognize faults by the sound of the machine. Comments are made such as: 'You have to hear, to feel if its running smoothly'. The same is also true for tactile contact to work equipment, for example, in the use of the hand: 'You feel it in your hand. The hand recognizes something. To mount a work piece, you need that feeling in your hands. You couldn't do anything with just a gauge. A gauge is only important in confirming what your hands feel and tell you.' And in the case of visual perception: besides having to read off measured values and scales, you have to have the 'right eye' for material properties and tool wear and tear. Here, too, it is emphasized that, 'only a skilled worker with a feeling for it would see that.'

Sensory perception is closely connected to a specific *relationship* to the machine and the materials. Skilled workers have not only an objective and

impersonal relationship with their machines, but also an extremely 'personal' one. One hears of skilled workers being 'fused with' or 'married to' their machines and that 'man and machine make up a unit'. Neither the skilled workers themselves nor their superiors see this merely as an expression of some kind of personal need. They stress quite emphatically that this kind of relationship to the machine is necessary because each machine has its 'bugs', and even two identical machines each have their own peculiarities. For this reason it is necessary to have an 'intimate' knowledge of the machine.

It is characteristic for the skilled worker's *handling* of machines and of the way he works that he does not work 'on' the machine inasmuch as he sets certain work processes in motion or operates the machine. Instead, he works 'with' the machine as if it were a tool. For this way of working it is essential for the skilled worker to believe that the machine only executes the desired processes because he is operating and controlling it. The object of the work process is not the machine but the particular workpiece being processed by the machine. Correspondingly, the processes being executed by the machine become a part of the worker's own operations and are directly connected with them – the same as with a tool. Here are some typical statements to corroborate this: 'The machine is like a tool to me. After all, on their own, conventional machines cannot do anything at all, so the machine is like a tool'. Tools in this sense are seen as something belonging to one's person, representing a sort of extension of one's own 'organs'. In this connection it is essential to be 'able to handle' the machine. An important basis for this is manual control, i.e. control via knobs and handles. As one skilled worker expressed it: 'With the knob in your hand, you have the machine under control. I can feel what I'm doing in my hands'. By proceeding in this way, the worker is adding a subjective dimension to his execution of the machine operations. This means he has to 'get fully involved' with his machine – or in the words of one skilled worker: 'That is, so to speak, getting into the machine. It hurts when the machine is running badly'. Even though work with the machine proceeds according to a strict schedule, workers execute the individual machining operations step by step. Typical is a way of working which displays the characteristic dialogical or interactive action: each step in a process builds on the one before it by taking into account the preceding results. This means that in a sense the material's 'response' to a processing step is taken into account. Experimenting with the machine and thus gradually finding out its full capacity for performance plays an important part in this regard.

Feeling plays a part in this way of working not merely in the sense of affective satisfaction or job motivation. Instead, it is an important basis for perceiving, recognizing and assessing the properties of materials and

machining operations and for regulating the execution of jobs. This is particularly clear in the case of the sensory perceptions described above. What is perceived and the way in which it is interpreted takes place to a large extent on the basis of feelings. Examples of this are to be found in such statements as: 'What you hear or don't hear depends on whether you have a feeling for it or not.' Similar statements are heard in the case of visual, optical perception: 'Everyone sees things differently and if someone doesn't have a feel for it, then he simply can't see it; it's a matter of feeling.' What is most significant here is the fact that 'intuitive perception and judgement are not in any way seen as being 'just a feeling' which would lead to uncertainty and only tentative assessments. On the contrary: it is precisely the intuitive assessments which lend certainty and confidence in handling both machines and materials. Therefore, feelings are assessed as a necessary prerequisite for carrying out a task in the same way as theoretical and expert knowledge. This becomes particularly clear when theoretical knowledge is compared with feelings. Seen from the point of view of the skilled worker, technicians and engineers often lack the right feeling: 'An engineer knows an awful lot, but he has no feeling for it. Only the skilled worker has that' – is one of many typical statements.

We should not jump to the conclusion that such a way of working can be explained by the skilled workers' inability to proceed according to the criteria and findings of technical, scientific rationality – in the sense that they lack the qualifications. On the contrary, it is clear that if they concentrate exclusively on such criteria, they would not be able to fulfil the tasks and challenges that face them. Points that should be stressed in particular are: peculiarities of the material, i.e. different material properties that are influenced by a number of factors which cannot each be identified and measured individually; variations within basically similar work processes as well as deviations from the norm; peculiarities of individual machines ('bugs') and the necessity to improvise and take into account the unpredictable, particularly with new products and when correcting errors.

Our empirical findings suggest that such ways of working are far more than a preliminary stage on the way towards scientific analytical thinking, or indeed, basically inferior to such thinking. They tend, rather, to be an independent and – in this sense – qualitatively different form of 'grasping' reality which is needed to complement the technical, scientific way of getting to the bottom of the production process.

USING NEW TECHNOLOGIES

The following sections will show in what way those elements of work

based on subjectifying actions are effected when computer-based information and control technologies are introduced.

Our studies centred on activities at CNC-machines. According to our investigations, the most important technical and organizational changes when using CNC-machines as opposed to conventional production technology are:

1 Control over the machines ensues from a computer program by which the actual production runs and individual machining steps on the machines are directed. 'Manual control' is also changing as the result of electronic control equipment.
2 The creation of programs can be organized along various lines. Centralized programming in the planning or technical departments and the so-called 'shop-floor' programming directly at the machine roughly represent the two poles of work organization solutions.
3 Individual machines are more complex, i.e. several machining operations are being performed on single machines (especially machining centres).
4 Machines are increasingly enclosed.
5 As a rule the use of CNC-machines goes hand in hand with flexible assignment of personnel and a proliferation of shift work.

Our studies concentrated on activities that can be termed skilled work. For the most part the creation of programs in this area takes place centrally (i.e. not at the machine), but the skilled worker is still left with important functions to perform, such as: optimization of programs, i.e. their adaptation to the actual conditions of the machines; running in of the programs; inspecting and monitoring the performance of machining operations; correcting malfunctions. This is why activities of this type are also referred to as skilled work tasks with 'de facto competence to act'. Studies show that activities of this kind currently predominate in the production of small and medium-sized series.[17]

In existing studies in industrial sociology, these developments are assessed mainly positively, especially when viewed in contrast to a lowering of skill requirements toward semi-skilled production.[18] However, our investigations reveal that the subjectifying coming to terms with job requirements is affected in several – partially contradictory – ways by these developments. It is under these working conditions where you will find some major reasons for a number of new problems and risks in the work process. There are signs in particular that:

1 The subjectifying execution of job requirements is being repressed, undermined and impeded, yet at the same time

2 new requirements are arising for subjectifying work activities, but the necessary technical and organizational foundations are lacking.

These two developments are interactive in the actual work situation. After they are described briefly, attention will be drawn to the associated stresses and risks for workers.

Repression of subjectifying work-related action

The key to this change does not lie in particular factors, but is more of a syndrome, in which changes in the control system and in the outer appearance of the machine (notably its casing), the flexible assignment of personnel and greater integration of on-the-machine activity within the overall production sequence are mutually reinforcing. These developments are leading to a complex change in work overall.

Skilled workers and their superiors share more or less the same opinion with regard to the relationship to machines: 'Of course, there isn't the same kind of relationship with the new machines as there was with the conventional ones.' At the same time, it is always stressed that: 'Intimate knowledge of the machine isn't important anymore. You don't need to be intimate with the machine any more.' Some superiors and management representatives no longer think it desirable for skilled workers to have such a close relationship to the machine, because: 'It must be possible for the CNC-worker to rely fully on the proper functioning of the machine . . . What's important for the person at the machine is what comes out of the machine. He doesn't need to be interested in the machine's inner workings.' Flexible assignment of personnel is yet another obstacle to the development of a machine–worker relationship of the type described above.

Use of electronic controls is resulting in an important change for the handling of machines (way of working). The manual control that remains is restricted essentially to pressing a button or activating a switch to trigger the desired operations. The possibility of regulating machining operations directly (as the worker experiences it) is thus limited. Skilled workers emphasize that they have to rely on 'the machine doing the right thing', without being able to exert a direct influence on it. A typical comment in this regard is: 'You used to have the machine under control, especially when moving the spindle up to the workpiece. This used to be done by hand. With the CNC-machine the skilled worker has to rely on the machine moving up to the workpiece at high speed and stopping at the right point.' This is why infinitely variable speed control is considered a major advance in the design of control systems. The man at the machine, so it is stressed, 'has nothing left in his hand'. These changes are often illustrated by the

example of driving a car. You have to imagine driving a car that is controlled by just buttons and switches and no steering-wheel. Then imagine the situation where you are sitting in such a car approaching a house at a speed of 100 km/h, and you have to rely on it stopping two meters in front of the house or reducing speed in good time to drive around a bend – whichever is programmed. Everything has to be planned in advance. In the actual execution of machining operations you have to 'trust' both the technology and the programs. On a CNC-machine it is no longer possible to perform the various machining operations 'step by step' and with each step succeeding from the last as with conventional machines. For workers the consequences are: 'It used to be possible to watch and make decisions during the machining operation with the intention of delaying tool wear by lowering the cutting rate. You can't do this any more. You have to decide and plan everything in advance. Direct reactions to changes in the work process are impossible. The most you can do is switch off prematurely.'

The change in sensory perception in light of these developments makes it clear that the loss of direct 'graspable' control and influence of the machine is a central point. One of the main differences between a CNC-machine and a conventional machine is emphasized thus: 'There aren't any handwheels any longer on a CNC-machine.' The important thing here is that the skilled worker used to be able to 'sense in his hand' what he was putting into effect. Even the visual perception of the machining operations is being obstructed and impeded. The main factors here are: higher speed; complexity of the machining operations, making it impossible to view everything 'simultaneously'; encasement of the machines, obstructing access to the machine and impairing visual contact. These changes are mutually dependent. High speeds, for example, necessitate the use of coolant, and lead – in the event of tool breakage – to a higher risk of accident. Therefore, the machines must be increasingly encased. But: 'One's view of the machining operation is reduced by the encasement.' In an extreme case this means: 'If you can't see anything any longer, you have to rely on the program, and that's very unsafe.' And finally, there is also impairment of the worker's acoustic perception. Certainly, the greater protection against noise and dirt provided by the encasement is viewed positively. But this also 'makes it more difficult to set up and run-in the machine, because you can no longer hear and see as well as you used to'.

For skilled workers, a major factor in the impairment of visual and acoustic perception is the (poor) accessibility to the machine. It is no longer possible, or at least not to the same extent as it was with a conventional machine, for a worker to arrange and alter his distance and angle of vision to the machine – to suit requirements – by moving the whole body. To use

the skilled workers' own words, you can no longer 'go straight up to' or 'walk around the machine'.

Finally, the worker's intuitive judgement and discernment are impeded in various ways by these developments. Far more than on conventional machines it is necessary to set up the 'empirical processes' in objectifiable scientific and technical data and in (mathematical) relationships. The development of intuitive judgements is getting impaired to an even greater extent. This finds clear expression in a skilled worker's assertion that: 'In the long run, CNC-workers are losing their skills by working on machining centres. They no longer come into contact with the workpieces in these situations. Part of the worker's skill, namely his sense of precision, is vanishing.'

The need for subjectifying work-related action remains and is developing new forms

CNC-machines place requirements on workers, which – according to our analyses – they can only fulfil through subjectifying work action. In spite of the changes mentioned above, companies stress that the most crucial factor in the optimization of programs and the monitoring of machining operations is the skilled worker's special knowledge of the practical situation.[19] A machine company owner's comment is typical in this regard: 'The skilled worker continues to be important because of the unpredictables, it isn't possible to plan for everything. Nothing can be planned 100 per cent.' And this tallies with a skilled worker's assessments: 'The skilled worker's contribution is his knowledge of practicalities in the CNC field. The skilled worker contributes his practical experience as a supplement to the program during optimization. This is the point where the skilled worker is vital.' Skilled workers and their superiors also share the opinion that it is as important now as it ever was for the skilled worker to be able to 'hear' tool wear – when monitoring the machining operations – so as to be able to intervene in time or at least prevent consequential damage. The resultant situation is thus a contradictory one for skilled workers. On the one hand, the technical and organizational bases for subjectifying interaction with his work are impaired, but on the other hand, these actions are necessary at CNC-machines. In the actual work situation this means that skilled workers try to engage in subjectifying work actions – in a sense – against the flow of changes dismantling such actions. A few examples of this follow.

1 Skilled workers try to acquire 'trust in technology', even at CNC-machines. Here it is important – as is partially the case with some newer

control systems – for the speed to be directly regulatable when running in the machine and when optimizing the program. The following comment is typical in this regard: 'You feel safer with a switch you can keep pressed down than with one you just turn on and off. I know that what I'm doing at that moment, the machine is doing, too.' If this is so, you have the feeling – at least to a limited extent – of 'having a grip' on the machine, even if it is a CNC-machine.

2 To improve visual perception – especially during optimization and running in of programs – the worker will try to open the machine casing or enter into the encased machining operation.

3 One response to impeded visual monitoring is to shift to the sense of 'hearing'. In the words of one skilled worker: 'When you can't see and can't get a look inside, you've no option but to listen.' An assertion typical in this regard is: 'I monitor 60 per cent by ear and at most 30 per cent by sight. For the remaining 10 per cent you can't do anything.'

4 Skilled workers on CNC-machines develop an ability that may be termed 'abstract perceptiveness'. What this means is creating a mental image of processes and operations, independent from direct sensory perception. It is important when operating buttons and switches, for example, to imagine which operations are being triggered on the machines and what the machine is doing. To quote a skilled worker: 'Only when you have an idea of what the machine does will you be able to reconstruct the action.' Skilled workers describe it in these terms: 'You used to feel it in your hand when turning the crank. Today you have to sense whether the machine is doing something, without touching anything.' The same is done when checking the program: 'With complicated parts I drive the program step by step. I imagine in my mind what the machine is doing.'

5 Finally, skilled workers, when monitoring machining operations – in the so-called 'down times' – try to behave in a way that is not just 'passive and reactive'. Even when they seem to have 'nothing to do', they are trying to reconstruct the machining operations and 'stay on the ball'. Secondary activities such as reading the newspaper, doing crossword puzzles or chatting with colleagues are not a contradiction, but actually make possible or support the work. These secondary activities, in fact, create a situation in which the workers can 'immerse' themselves in their work and – as on conventional machines – 'be on the ball with all five senses'. A foreman's comment was: 'Reading a newspaper doesn't have a negative effect on work. On the contrary. People want to have something to do to stay attentive. It's funny and strange – but the work doesn't suffer from it.'

New types of strain

Skilled workers need to employ their 'old' skills on CNC-machines, too, but – as has been shown – their attempts to do so are simultaneously obstructed and impeded in numerous ways by changes in technology and work organization. Our findings show that it is precisely this contradictory situation which contains important catalysts for a number of new sources of strain and risk for workers.[20] Here, these can only be summarized briefly as follows:

1 Skilled workers feel overtaxed and under pressure, because on the one hand they are responsible for the machine, but on the other they 'don't have it under their control any longer'. It is notable that demands on the workers' responsibility are tending to increase rather than decrease due to the higher costs of the machine, increasing down-times and defective piece production. The following summary drawn by a foreman can be taken as typical of this situation: 'The greater stress arises because the skilled worker has more responsibility for the products than before, but is less and less able to influence and control the machine.'
2 Skilled workers are subjected to mental stress because they have to concentrate more and always keep their minds on their work. This stress does not arise because the workers are unable to concentrate or think in mathematical terms and programming rules. They are caused more by the fact that the skilled worker's task – as opposed, say, to a programmer – is to consider the practical conditions on the machine at the same time as the theoretical ones. For them it is not only important that a program be correct. It must also prove successful in actual practice on the machine. Even a perfect program can prove deficient if certain particulars of the machine and the material were not taken into account. Yet precisely this is what is difficult to calculate in advance, and is, in any case, possible only to a limited degree. The skilled worker is under pressure, therefore, always to think of 'what might happen.' and 'whether they've thought of everything.' He is never certain of himself because his questions cannot be answered until the machine is running. And in most cases it is no longer possible to prevent the defects that then arise. This uncertainty means that the skilled worker is unable to 'switch off' in his spare time. To quote one skilled worker: 'You have to have everything in your head. And if you're having to think all the time whether everything's o.k., whether you've made a mistake or forgotten something, you simply can't switch off after work. You keep running mentally in top gear – and that's stress.'

If skilled workers try to transfer the working methods customary on

conventional machines to a CNC-machine, they will feel more secure on the one hand, but they will also end up with new problems. If the casing is opened when the machine is being run, or if the workers enter the machining space, there is a greater risk of accident. If they try to be guided by the noise of the machine, this is all the more difficult because of the overall higher noise level – not to mention the effect of removing the machine casing – and requires a higher level of 'concentration'. Attempts to listen to the 'right' noise results in a higher sensitivity to other sources of noise and thus to higher stress on the psyche and nerves.

If skilled workers try to fill their down times with secondary activities, they find themselves in conflict with job discipline. There is also the risk that these secondary activities will be used as a reason to give them extra jobs to do (especially operating several machines). 'Side jobs' of this type, however, make it difficult to have the necessary attentiveness. It is possible simultaneously to monitor a machine by ear and read a newspaper, but not both to monitor one machine and optimize another. Workers are forced, therefore, either to forgo secondary activities, such as reading a newspaper, or else to keep them secret. In the words of one skilled worker: 'The skilled worker used to be on his toes. Today he just needs to pretend to be on his toes.

Problems arise even when skilled workers adapt to the new situation. For workers this means they have to reconcile themselves to no longer being able to influence and control the new machines in the same way as conventional machines. This means you just have to 'grin and bear the increasing problems'. More than anything else this entails 'having to become thicker skinned and trying "not to be so sensitive about the work any more"' – in either the positive or negative sense. But not only does this make the work less interesting and satisfying, skilled workers also run the risk of being considered unreliable, irresponsible, disinterested and unskilled. In other words, they are putting into question precisely those qualifications and working practices on which a company's interest in the use of skilled workers is essentially based.

Finally, there is the risk when working on CNC-machines of forgetting or of no longer being able to learn and develop that special 'empirical knowledge' of the skilled worker. The prevailing opinion is: 'You can't learn these essential basics on a CNC-machine. If you had only CNC-machines – it wouldn't work out.' In the skilled worker's eyes, 'Work on conventional machines is important for getting a feel for what a machine does and can do.' It is, above all, the experience which is acquired on conventional machines and transferred to the CNC-machine that plays an important part in precisely this capacity for 'abstract perceptiveness'. But how is such 'empirical knowledge' to be acquired in future if production –

particularly in conjunction with a more extensive interlinkage of data systems (CIM etc.) – is converted increasingly to CNC-machines. This is a problem that is just beginning to emerge, and one which appears to be intensifying.

CONSEQUENCES FOR FUTURE ANALYSES OF WORK AND OPEN QUESTIONS

It is a common opinion that the problem outlined in this paper is only a question of short-term adaptation and transition. Our findings, however, do not speak for such an assessment. More investigations have to be carried out to see to what extent such developments occur in other areas of production and whether the results of this study can be generally applied to the use of information and control technologies.

On the basis of our results up to now it is clear that the repression of subjectifying action as well as the contradictory demands made on workers have to be investigated more closely. The question involves developments which cannot merely be limited to dequalification as in the case of Tayloristic work forms. The greater weight placed on objectifying actions at work could result in a maintenance, and even the creation of 'qualified tasks', as well as an expansion in the scope of job discretion and decision-making for workers. The main issue here, however, is the qualitative changes in the qualifications necessary in the work process. Therefore, it does not make any sense to put these changes in categories such as 'more – less' or 'higher – lower'. For future investigations it is necessary to clarify in what ways the skilled worker tasks described here appear in other areas of industrial production, especially in process industries.

The repression of subjectifying actions does not lose any of its power just because in practice it turns out that such work actions are still necessary. On the contrary, as our findings show, even though 'empirical knowledge' is expected from workers as before, the foundations and preconditions for the necessary (subjectifying) work actions are endangered. The design and development of the technical system are overwhelmingly oriented to the objectification of work actions.

Our investigations demonstrate that subjectifying actions at work are an important part of what the worker can contribute to the work process. A central question surrounding this issue is what effects, both within and outside of the company, can be expected if the development and application of subjectifying work actions are endangered. Future studies will have to clarify not only how this leads to new problems in the production process, but also what deep-seated changes could occur in dealing with life outside of the workplace.

In terms of the design of technology and work organization, we are not trying to portray work forms for the skilled worker on conventional machines nostalgically. It is impossible to ignore the existing strains and restrictions that have characterized conventional tasks in industrial production up to now. The question is not one of a return to 'old' technology. The decisive point is to discover whether it would be possible and which practical approaches might exist to set up future developments in technology and organization systematically so as to facilitate the use of subjectifying action at work.

Social scientists have the challenge to take the analyses of work outlined here and develop them further both at a theoretical and conceptual level as well as at an empirical one. There is no doubt that this research issue is one which extends beyond the boundaries of industrial sociology. This topic can only be dealt with 'collectively' through interdisciplinary research. We hope that the analysis presented here will act as a stimulus for this future research.