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Action Regulation Theory: A practical tool for the design of modern work processes?

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Winfried Hacker

Department of Psychology, Dresden University of Technology, Germany

Action Regulation Theory is not only a description tool but also a normative guide to efficient and humanized work; it became a foundation of international standards in work design. The regular mode of action regulation is knowledge-based regulation. Innovation in mental work, e.g., product development, follows a hydrid model of action regulation combining knowledge-driven opportunistic sequences with systematically planned episodes of work. Innovative work can be improved by facilitating an interaction of mental and psychomotor operations in action: Thinking in and by action is a general principle of innovative mental work. Action Regulation Theory might explain why, in product development, a hybrid type of cooperative work is more effective than both, group work or individual work.

WORK PROCESSES AT TIMES OF GLOBALIZATION AND SOCIOECONOMIC CHANGE

Decrease or increase in the impact of Work and Organizational Psychology contributions?

In recent years there have been two major developments in Europe that constitute important challenges for Work and Organizational Psychology (WOP). First of all, work has become increasingly deregulated. And second,

Requests for reprints should be addressed to W. Hacker, Dresden University of Technology, Department of Psychology, D–01062 Dresden, Germany
Email: hacker@psychologie.tu-dresden.de

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despite the widespread increase in automation, there has also been an increase in the number of work places, although they are limited in time, require mobility, and do not offer job security. Thus, work, paid and unpaid, has not become less important. Therefore, it is important to focus on the *core of work,* and that is *acting*. This is now even more essential than some time ago, since the current and new work activities, that can be found in the technology sector and in the knowledge intensive service sector (i.e., education, business, and health), are jobs with high levels of responsibilities. In these jobs the cognitive requirements are prevailing. Twenty percent of the new work places created in the EU since 1995 are in the high-grade technology sector, and 70% are in the knowledge intensive service sectors. By way of contrast, the practices and tools for psychological analysis, evaluation, and design of high-level mental work activities still need further improvement.

The changes in work requirements are not only consequences of the fact that tasks are more mentally demanding, but are also due to rapid changes in the *labour market*. Whilst jobs with high cognitive requirements are disappearing, there is at the same time a shortage in highly qualified and skilled labour. This contradictory situation in the labour market has affected job contents in three ways:

- The increasing time pressures impede social support at work, and increase the probability of role conflict. This has already been shown, for example, in the analyses of Scandinavian Health Care Systems some years ago (Lindström, Kiviranta, Bach, Bast-Pettersen, & Toomingas, 1994).
- A critical situation in the labour market has a deteriorating effect on the task-specific well-being of employees (Figure 1; Schroda & Hacker, 2001).

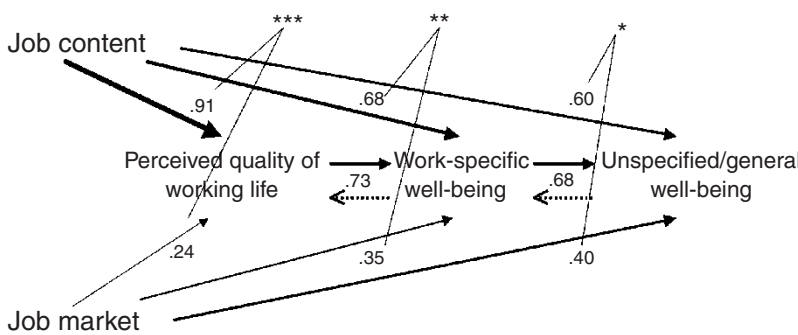


Figure 1. Results of a risk analysis. *$p = .05$; **$p = .01$; ***$p = .001$.

- Increased flexibility and mobility seem to be counteracted by standardization and regimentation, even of high-qualified work, at the expense of autonomy at work, a well-known buffer against stress.

ACTION THEORY: THEORIES AS USEFUL TOOLS? A EUROPEAN APPROACH

Action Theory: A descriptive tool

Work is not a value *per se*. Human-centred work design should follow the European humanistic line of thinking in the tradition of, for example, Albert Schweitzer, Kurt Lewin, Vygotski, or Leontjew. A simple behaviouristic stimulus–response approach would be too limited to analyse human work activities and their components and the actions that are motivated and regulated by higher-order goals (Hacker, 1993b).

Goal-oriented work activity is organised in cyclical control loop units, the TOTE (Test–Operate–Test–Exit) units, which are interlocked in a hierarchical manner (Figure 2).

Thus, activities are to be described in terms of sequential phases and hierarchical "levels" or modes of control. Roughly, three levels of conscious awareness of the processes and representations that simultaneously regulate work activities can be distinguished:

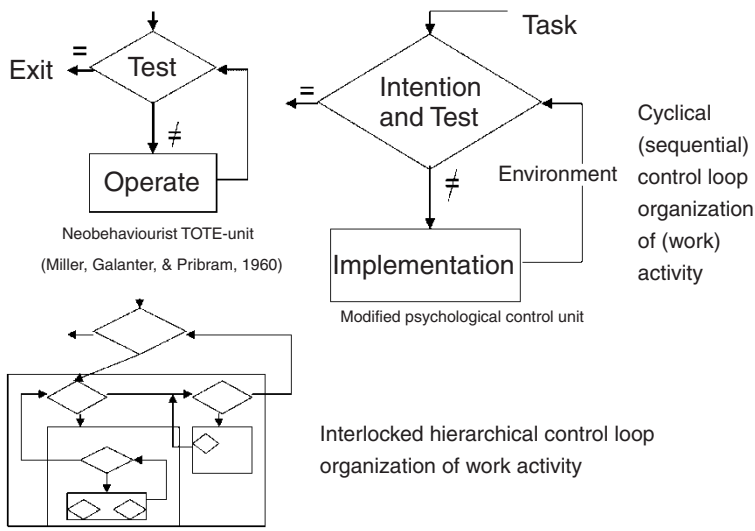


Figure 2. Control loop of organization of work.

(1) An automated, unconscious mode of regulation.
(2) A knowledge based and possibly conscious mode.
(3) A strictly conscious intellectual mode (Figure 3).

The top-down approach and the span of the hierarchy implies that the highest of these levels includes and determines the lower, unarticulated, or implicit and automatic levels. However, in terms of action regulation, the underlying levels have a certain amount of regulative autonomy and the possibility of a bottom-up impact on higher levels.

Unfortunately some European standards (e.g., the EN 614-2) that use these approaches apply the terminology of ''skill-based, rule-based, and knowledge-based behaviour,'' which is unsuitable in this context. Because, first of all, this conception ignores the fact that knowledge of rules is knowledge too, and second, it disregards the intellectual processes, e.g., reasoning or problem solving, which regulate a lot of work tasks.

The aforementioned levels relate to various *phases or stages of action regulation*. The first stage is ''action preparation''. It includes ''orientation on the task'' and ''redefining the task into a self-set goal'' (Hacker, 2002b; Hackman, 1969). The orientation stage focuses on the conditions under which the goal has to be accomplished, the availability of methods and strategies, and assessing the degrees of freedom to choose different methods. Furthermore, the co ordination of one's own actions with colleagues is also part of this orientation process. The final phases are ''implementation'' and ''evaluation''. The implementation process is guided by continuous feedback on goal accomplishment, and is completed with an evaluation of the final outcome in terms of economic task criteria (Hacker, 1985a, 1985b, 1989, 1994, 2001).

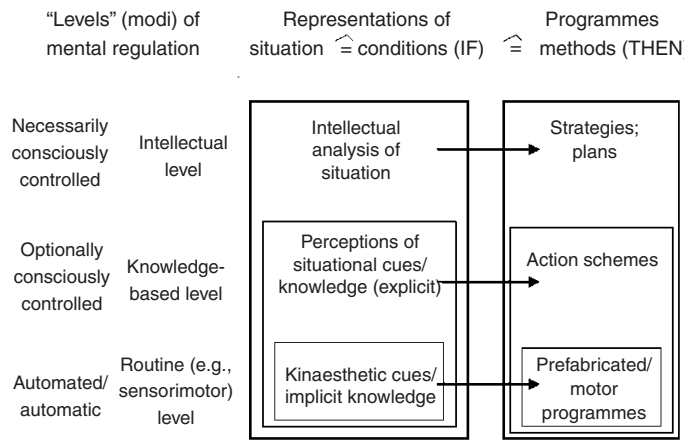
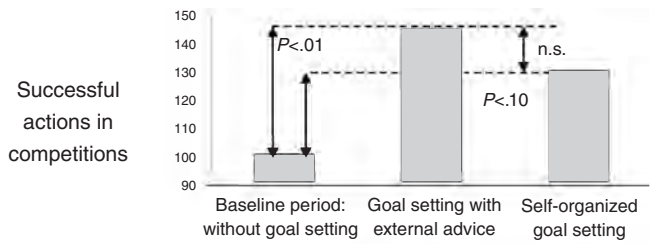


Figure 3. Levels of mental regulation of activities.

The most important characteristic of action regulation is that actions are controlled by *goals*, that, from a cognitive perspective, can be seen as anticipations of the results that one intends to achieve. From a motivational perspective these goals can also be seen as intentions. These goals can be decomposed into several partial goals that together constitute the main goal. Furthermore, the goals that regulate our activities are stored in our memory, until the action has been completed, as a representation for what the final result should look like. Moreover they are also the starting points of the emotions that are inherently associated with our actions, e.g., perceptions of success or flow (Hacker, 1985c).

Is there any practical impact? There are several well-tried techniques and tools of work analysis and work design that are based on the approach described above To mention only one example: The crucial role of goals in action regulation is applied in Pritchard, Kleinbeck, and Schmidt's (1993) powerful goal-setting and feedback techniques.

An example: We applied two different versions of goal-setting techniques in the training of a professional volleyball team for a competition period: goal setting with an adviser and self-administered goal setting of the players. A significant increase in successful actions in the competitions was achieved with both techniques. These improvements can be explained by the percentage of players who reported applying precise and specific goals and receiving continuous specific feedback from their trainers, who were qualified in applying these techniques (Figure 4).



Share of players reporting		Without Goal setting	With Goal setting
• specific goals		25%	83%
• regular	feedback of trainers	17%	100%
• specific	feedback of trainers	25%	83%

Figure 4. Results of goal setting during a competition period of professional volleyball players (above) and supposed main sources of the improvements (below).

The aforementioned approach of *redefinition of the task* has great practical importance. ''Redefinition'' is a specific feature of a psychological approach that focuses on the mental regulation of work. It illustrates that mental regulation of activity is mediated by the object of that activity. To quote Brushlinsky (1989, p. 37), ''Human activity is always determined by its object *not* directly but in a mediated way, through its inner specific regularities'', such as goals, motives, knowledge, experience, or values. This approach was developed by the outstanding Russian psychologist Sergei Rubinstein (1914).

As is well known in Occupational Psychology, different persons, for instance subordinates or suppliers, perceive and interpret identical work assignments in a variety of ways. This variety in ''redefinition'' is due to the fact that people differ in knowledge, experiences, aspiration levels, or values (Hackman, 1969, 1970). However, along with this differential type of redefinition there is also a general one: The tendency of human beings to redefine tasks according to the principle of ''cognitive economy''.

What are the important characteristics of this crucial redefinition? Redefinition processes can comprise both *controlled* intentional aspects, as well as *automated* unintentional aspects. On the one hand, people can make a deliberate attempt to interpret and redefine a task, as is the case with complex or undefined tasks. (Design tasks in engineering or design processes are good examples.) On the other hand, there are unintentional and automatic perceptual processes, where patterns of stimuli are automatically processed in terms of previously experienced and therefore expected information, and that lead to comprehension of the task.

Redefinition is a *relational* concept: The demands that tasks comprise are related to the personal resources of an individual that are relevant for the particular activity, such as relevant knowledge, skills, abilities, values, aspiration levels (Lewin, 1926), or the amount of effort that people think they will have to invest. Consequently, redefinition comprises a prospective *cognitive and emotional evaluation* of the tasks, for example, people may think this task is probably tiring, boring, or stimulating. This prospective evaluation will determine *what* the person will actually implement and *how* he or she will do it.

Are there different types of redefinition of work orders into self-set goals? Redefinition processes can be roughly categorized as either ''translation'' type of processes or ''reinterpretation'' type of processes:

- In translation-type processes of redefinition, the result of the activity is (more or less) equal to the task that was intended. Only the means of accomplishment may differ from what was intended.

- In reinterpretation-type of processes of redefinition, the results obtained may differ in various ways from the results as they were intended when the original assignment was issued. Reinterpretation can specify an ill-defined or complex task or it can modify the results with severe deviations from those intended in the task.

With regard to the *translation type*, any complex task must be decomposed into a chain of partial subgoals for which step-wise accomplishment is required in order to complete the total task. The retention and reactivation of future goals and subgoals is an activity labelled "prospective memory". Future goals and activities are often time-based, for instance calling somebody at 2 p.m. exactly. People typically try to translate time-based prospective tasks into event-based tasks ones, for instance calling just after the lecture.

This translation type of redefinition may be the result of an anticipation of high memory load in the case of time-based tasks. Following the principle of cognitive economy, people try to use external cues, or even generate new ones, in order to reduce their mental effort. In a series of long-term field experiments we verified this assumption (Hacker, Auerbach, Hagendorf, & Rudolph, 1999; Hacker, Herrmann, Pakossnik, & Rudolph, 1998a). Nearly half of the participants in this experiment spontaneously translated their time-based tasks for a 6 week period into event-based tasks, thus transforming the heavy load of self-initiated retrieval into an environmentally cued task with significantly lower chances of forgetting.

With regard to the *reinterpretation type of redefinition*: In design tasks, such as engineering design, a complex and initially vague question of a customer is interpreted stepwise until the requirements are clarified. In this initial phase, the designer identifies and specifies the problem that must eventually be solved. The reinterpretation type of redefinition here concerns a transformation of an ill-defined problem into an identified, well-defined, and, in this way. solvable problem.

Finally, redefinition as a reinterpretation can lead to different results than those that were originally intended in the task. The case of geriatric nursing can illustrate this point. In order to cope with the problem of under staffing in hospitals, due to economic reasons, nurses often seem to have modified their strategies. In these situations nurses may change from nursing that includes time-consuming programmes to activate the old people, into nursing that is characterized by quietening down the old people by using medication. As a result the overload is reduced and the economic aspects of the task are met, but the humane aspects are neglected.

Action Theory: A normative guide to efficient and humanized work

Action theory proves its value as a normative guide in work design and redesign, since it simultaneously aims at efficiency improvement as well as at humanisation. In short, it highlights ways of *efficiency improvement by humanization* (Hacker, 1985d). This is laid down into the approach of complete vs. partial tasks and activities. Originally this approach was initiated as an ethical impulse by the humanist philosopher and physician Albert Schweitzer, when he discussed industrial culture (Schweitzer, 1971).

Activities can be considered to be *sequentially* complete when they do not merely allow people to execute the task, but also allow them to do the required preparatory cognitive operations (in particular goal setting and deciding on the measures to be taken). These cognitive operations are particularly necessary when people participate in organizing the work, and checking the results of one's work. Moreover a task is considered to be *hierarchically* complete, when the mental regulation is not limited to automated processes, but requires controlled, i.e., knowledge-based and, moreover, intellectual control processes as well (Hacker, 1986a).

Sequentially and hierarchically complete activities offer the crucial option of learning, as opposed to deterioration skills and abilities in simple and limited routine activities. Decision latitude (or autonomy) is the most important feature of complete activities. Complete activities offer the decision latitude that is necessary for setting one's goals. These are prerequisites of comprehensive cognitive requirements of a task, and determine the intrinsic task motivation, i.e., being motivated by a challenging job content. These aspects serve as a well-known buffer against negative consequences of high workload.

Is there any practical impact? The extent to which the task is sequentially and hierarchically complete can be assessed by analysing a limited number of task characteristics Some of the W&O Psychological tools for the assessment, evaluation, and design of jobs are based on these characteristics, which are rooted in Action Theory. One of these instruments—the Task Diagnosis System, developed in the Dresden Group—is a computer-aided tool. This enables simulation of the effects of job design or redesign, and allows assessment and evaluation of different versions of the design options, and assessment of their impact in terms of fatigue, monotony, affective aversion against the job (satiation), and stress (Hacker, 1993a).

In the following example, three versions of a pharmaceutical production technology are compared: An older manual version, a newly automated CAM-technology based version, and a redesigned version based on humanized CAM-technology, developed with user participation. The reason for the redesign was that the automation had reduced the mental demands, and this has led to monotony and affective aversion (see Figure 5). The redesign successfully improved (Figure 6):

- The percentage of operations that required activity of the operator, as opposed to passive monitoring.
- The sequential completeness of the task, because operations concerning inspection, organization, and cooperation, and hence task-related communication, were added.
- The hierarchical completeness of the task by adding some planning requirements.
- Procedural autonomy, to a small extent.

Nowadays *international standards*, such as the ISO 9241-2 or EN 614-2, call for "complete tasks" that offer task variety, allow employees to use their skills, experience, and abilities, and stimulate learning on the job. Hence, the suggestions and results of W&O psychologists have been incorporated in international standards for work design and redesign. Despite the variety of economic branches and diversity of technologies, there is clearly a societal

	Well-being (BMS II)				*Satisfaction with application of qualification*
	Fatigue	*Monotony*	*Affective aversion*	*Stress*	
Manual technology	without	negligible	without	without	satisfied
CAM implemented	without	high	extremely high	without	neither satisfied nor dissatisfied
CAM improved	without	without	negligible	without	—

Comparison of social effects of manual and CAM-technologies:

frequency of task characteristics Which should be redesigned (TDS):		Global evaluation of task design
	• manual technology:	6
	• CAM implemented	12
	• CAM improved by participative redesign:	4

Figure 5. Comparison of the design of three versions of a pharmaceutical technology.

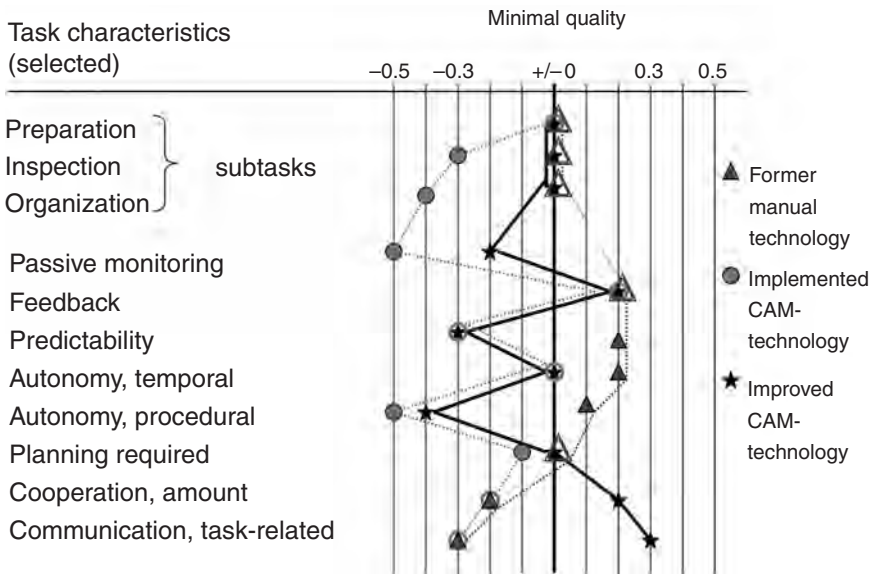


Figure 6. Profiles of three versions of a pharmaceutical technology (sugar-coating of pills). (Selected task characteristics from the TDS—Task Diagnosis System; Hacker, Fritzsche, Richter, & Iwanowa, 1995.)

demand for human-centred design of work. Nevertheless, and despite these successes, the WOP findings have to compete with continuous changing job requirements.

DESIGN OF MENTALLY DEMANDING WORK GUIDED BY ACTION THEORY

Knowledge-based action regulation: The psychological foundation of Knowledge Management

In the modern economy, Knowledge Management is considered to be an essential factor for innovation and profitability. Actually, the immense increase in technological capability to store and process data and information is in sharp contrast with the limited human capacity to apply knowledge while acting.

Action Theory first of all stresses that normally our actions are regulated by the knowledge and experience we have acquired at work; this is the regular mode for action regulation. Only when we do not know how to accomplish a goal, we try to solve the problem by thinking up new strategies, and only when the conditions are unambiguous and actions can

be repeated does it become possible to change action regulation into a mentally automated process.

More important, however, is that Action Theory issues warnings against some popular misunderstandings:

- First of all, we should make a distinction between *data*, *information*, and *knowledge*. Moreover, it is important to understand that not all kinds of knowledge are functional in action regulation. We have to distinguish between knowledge that only accompanies actions but does not regulate them, knowledge that can subsequently justify an action, and knowledge that is actually regulating the activity.
- However, even this last type of knowledge alone is not sufficient for action regulation. Imperative is that associations between intention and knowledge are established, or more precisely, the *Intention–Cue–Strategy patterns*. This means that only when a person has set a specific goal *and* has identified the relevant cues of the conditions under which (s)he will be able to accomplish the task, *and* takes the appropriate measures, will (s)he succeed.
- Substantial parts of the knowledge involved in action regulation are *implicit*, unarticulated pieces of knowledge that cannot be elicited by questioning alone.
- Finally, there is not "the" single, universal type of knowledge. Even the distinction between declarative and procedural knowledge cannot explain differences in performance. Knowledge is *content specific*: There is a content-related pattern of pieces of knowledge on goals, on situational cues, on causes, measures to be taken, means, partners, and finally consequences (Figure 7).

Is there any practical impact? The elicitation of expert knowledge, for the improvement of training, data banks, or software appears to be the bottleneck of Knowledge Management When crucial parts of expert knowledge are tacit knowledge, to be applied in a specific situation, or context, a situated elicitation-method should be more effective than a decontextualized interview. Situated knowledge elicitation should be integrated in the work process, and not be an additional external procedure (Hacker, Grossmann, & Teske-El Kodwa, 1991).

This has been demonstrated in our example where one group of employees was asked to engage in a 3-day self-analysis of their work processes with respect to goals, causes, cues, measures, etc., before they were interviewed, whilst another group was interviewed without such a self-analysis. The results supported our assumption. The amount of knowledge that was reported by the group with the self-analysis was significantly higher. Their members reported more situational cues and

methods, and this was the only group that reported about their goals (Table 1).

Moreover, if action regulating knowledge is a component of the Intention–Cue–Strategy patterns, the effectiveness of the process of knowledge elicitation should depend on various redefinitions of this elicitation task and, thus, on different self-set goals, possibly with a differing motivation.

The next example (Table 2) supports this assumption. People instructing a virtual trainee report more of their expert knowledge in a (virtual)

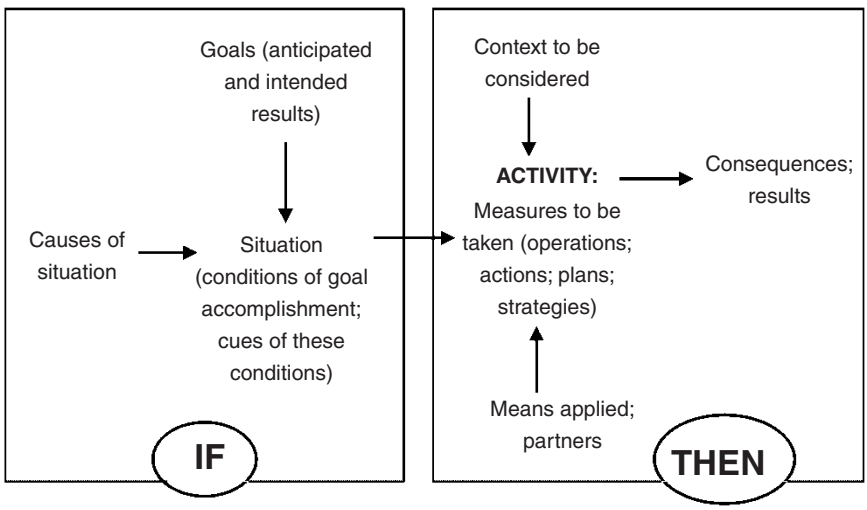


Figure 7. Types of action-regulating knowledge.

TABLE 1
Knowledge elicitation with vs. without a preceding 3-day self-analysis of the work process ($n = 15$ employees)

Knowledge areas (selected)	*Without self-analysis*	*With self-analysis*
Goals	0	4
Cues	43	75
Causes of situation	0	0
Methods	56	91
Context of methods	20	26
Consequences of methods	0	0

Elicitation effect (%) $= \frac{\text{number of reported items}}{\text{number of hypothetically relevant items}} * 100$
Dixon and Mood sign test ($p = .05$).

TABLE 2
Context effect on reported knowledge (mean total elicitation effect, %)

	Elicitation interview	*Tutorial dialogue*	*Significance of difference*
Quality inspection	45% (n = 6)	95% (n = 6)	.05
Bank counter duty	30% (n = 6)	37% (n = 7)	.05

Wolff (in Hacker, 1996).

dialogue with this trainee, especially concerning working strategies, than people answering the knowledge-eliciting questions of an interviewer.

Innovative mental work: Goal-directed, planned, and hierarchically organized versus ''opportunistic with systematic episodes''?

The globalization of economic competition has enhanced the pressure to be innovative. Innovations in artefacts and technologies—for example, machines, software, buildings, organizational strategies, or training methods—are the result of design activities, which are essentially problem-solving activities.

Design activities are of crucial economic importance, whether it is designing by architects, scientists, or engineers developing new technologies. In *all* kinds of work the design of new organizational solutions, new technologies and strategies, or new products is decisive in the competitive frontier. The European economy is in need of a type of work activity in which employees not only execute given orders, but contribute to the development of *new* and *more efficient* strategies. The approaches of contextual performance, proactive behaviour, organizational citizenship behaviour, personal initiative, or entrepreneurship (Bateman & Crant, 1993; Fay & Frese, 2001; Frese, Fay, Hilburger, & Tag, 1997; Hisrich, 1990; Organ, 1997; West & Farr, 1990) correspond with this type of work activity that goes beyond giving orders and prescribing strategies.

From an Action Theory point of view the abovementioned approaches may hint to a pattern of action characteristics that can be classified in terms of an ''innovative style of action'' vs. the usual ''repetitive style''. Ordinary repetitive acting corresponds with the ''given order with prescribed procedures'' method. Innovative acting includes the characteristics of ordinary repetitive acting, but is also aiming for improvement of procedures, working conditions, and results in order to enhance effectiveness or efficiency. Additional features can be distinguished in the *surface structure* as well as the *deep structure* of mental action regulation (Table 3).

TABLE 3
Characteristics of repetitive vs. innovative acting

Repetitive acting (predominantly accomplishing given orders in prescribed conditions)	*Innovative acting (additionally improving [organizational] conditions, strategies, and results)*
Procedure (surface structure)	
Meets given order, improvements of accomplishment within given frame in learning by doing	Additionally enhancing goals and improving procedures
Uses given opportunities for performance	Also develops new opportunities for performance
Uses working time for prescribed operations	Also carries out nonprescribed problem-finding and solving "surplus" activities
Personal prerequisites (deep structure)	
(a) *Attitudes*	
Improves given situation (in the best case)	Questions and exceeds given conditions and strategies
Cognitive analysis of given situation	Also reflection on situation and own strategies (meta-cognitive effort)
Analysis of concrete components of situation	Analysis of the situation as a whole system, identification of key characteristics, abstraction
	Conceptual analysis; switch between levels of abstraction
Concrete acting in present, real situation	Anticipation and planning
	Also considers possibilities, symbolic acting
(cf. "concrete" vs. "abstracts" attitude; Goldstein & Scheerer, 1941)	
(b) *Cognitive prerequisites*	
Goals	
Accomplish given order	Additionally, self-set goals are accomplished concerning changes of orders, organizations, or strategies
Mental model	
Action regulating mental representations concern prescribed procedures	Additionally, mental model of changes/alternative procedures
Knowledge	
Knowledge concerning given order/prescribed conditions	Additionally, (development of) knowledge on alternatives/procedures of change
Thinking	
Intellectual coping with given order/problem	Additionally, identification of problems

TABLE 3
(*continued*)

Repetitive acting (predominantly accomplishing given orders in prescribed conditions)	*Innovative acting (additionally improving [organizational] conditions, strategies, and results)*
Prerequisites in organizations	
	Complete tasks (cf. ISO 9241-2, EN 614-2) including autonomy with: – transparent, foreseeable, and controllable requirements – margin in timing "Psychological contract" especially concerning: – management of risks in innovation – job security – profit sharing

By definition the results of design activities are *unknown* at the start of such activity—as is often the case in problem solving, and therefore these innovative design activities cannot start from a well-defined result, which could serve as an anticipated goal. Therefore, the normal procedure of stepwise decomposition of an anticipated goal into hierarchically and sequentially organized subgoals, following the original widespread top-down model of the original Action Theory—which dealt with manual work—is impossible (Figure 8).

In contrast to this, design activities follow a hybrid model of action regulation, combining knowledge-driven or "opportunities using action sequences with systematically planned episodes" (Visser, 1994); (Figure 9). When a part of the solution is remembered from a previous time, this solution to a problem may be used again. In that case this procedure will be used as a starting point for this new problem, which means that the total problem will not have to be completely decomposed at first.

Is there any practical impact? Actually there are several important useful applications A first application refers to the rejection of inadequate methodologies that are taught at technological universities and of inadequate standards, like the German Engineering Society Standard 2221. These methodologies and standards are in favour of the inadequate strictly hierarchical top-down strategies.

A second consequence is that more adequate humanized design strategies can be presented. In empirical studies a pattern of procedural design characteristics has been found that corresponds with a high quality of

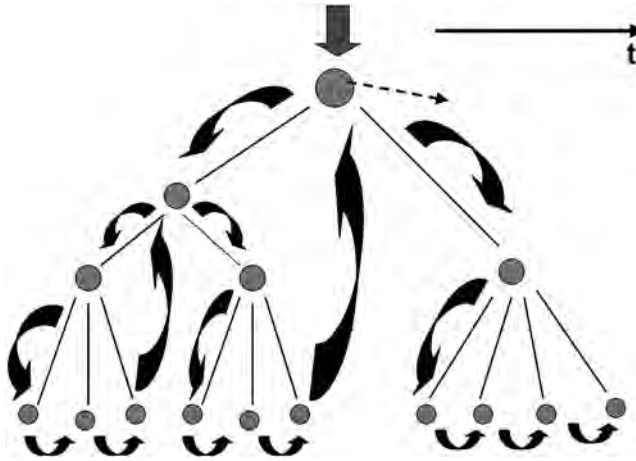


Figure 8. Original model of hierarchical and sequential regulation of actions.

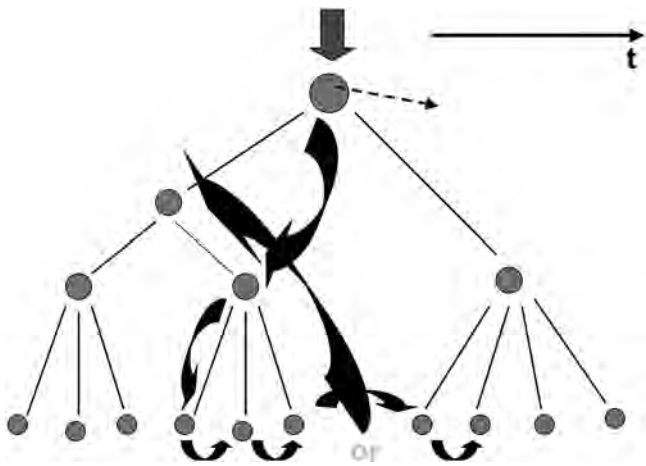


Figure 9. Opportunistic action regulation.

solutions. Table 4 illustrates this in a group of lay designers. The design process of those with the best design solutions was significantly different with regard to some procedural characteristics compared to those with the worst solutions. Better quality of the solution was related to a higher percentage of time spent on *mental processing* (thinking, reflection), a higher percentage of subjects working out *alternative solutions,* and a higher percentage of people who *switched* more frequently between working at sketches of the total system to be designed and sketches of system components.

TABLE 4
Comparison of procedural characteristics of design activity [two groups of participants with best ($n_1 = 10$) vs. worst ($n_2 = 12$) solutions: mean (M), standard error (SE)]

Procedural characteristics	*Solution quality*		*Significance of difference*
	Highest ($M \pm SE$)	*Lowest*	
Total time consumption (min)	43.3 + −5.1	21.3 + −3.4	.01
Time share of mental processing (without external activity) (%)	26 + −0.2	0.6 + −0/3	.05
Share of participants developing alternatives (%)	50.0	0	.05
Mean frequency of switches total system/components	2.9	1.2	.05

From Hacker, Wetzstein, and Römer (2002).

More generally, the following pattern of *characteristics of successful design activities* should be trained as components of an efficient hybrid design procedure:

- A thorough analysis of the task requirements.
- A profound understanding of relevant information.
- Using both analogical images and symbolic propositions in problem solving and frequent switching between these two.
- Searching for alternative solution principles.
- Reflective evaluation on final and intermediate results (Hacker, 2002a).

Action Theory—practical guide to the design of innovative mental work?

Job design is a well-established discipline within Work and Organizational Psychology. However, design of mental work, but also of innovative mental work—as the aspect of future European economic development—is less widespread.

In general, innovative mental work can be assisted by both:

- Computerization, that is by an allocation of functions such that people are relieved of some mental demands (Hacker, 1986b, 1987, 1989; Hacker & Schönfelder, 1986)
- Suitable tools and practices that can assist mental work.

However, in particular the most innovative parts of design activities can not be computerized, since they are by definition ill-defined and qualitative in

nature. Therefore, Work and Organizational Psychology should concentrate primarily on improving the tools and practices of designing innovative human work (Hacker, 1997; Hacker, Sachse, & Schroda, 1998b). Most of these practices have *general psychological principles* in common, which Action Theory describes as the interaction of mental and psychomotor operations of actions. Mental operations are, for instance, problem solving, reasoning, or decision making; psychomotor operations are writing, sketching, speaking, or gesticulating. Rubinstein (1984) described this interaction as *thinking in and by action*. The Theory of Internalizing external psychomotor operations and of Externalizing mental operations offers a model of this interaction (Galperin, 1967).

Following this line of thinking innovative work can be improved by facilitating exactly this interaction of mental and psychomotor operations in action.

Thinking in and by action—the example of manual sketching in engineering design as a thinking tool. Even in the area of computer aided design (CAD), manual sketching is still widely used before and during CAD-work. In a survey among 106 experienced mechanical engineers, about 70% reported that they made sketches in the preparation phase of their CAD-work and 60% during their work. More than 90% stressed the necessity of manual sketching in order to be able to develop drafts of solutions (Römer, Weißhahn, Hacker, Pache, & Lindemann, 2001).

An experimental study with 76 engineering students of three European universities, who were asked to design a drive assembly with a 3D-CAD program, revealed which characteristics of mechanical designing activity are modified by sketching. It appeared that the total number of operations, and especially repetitive operations, corrective, and checking operations, are *reduced* without extending the total working time when the students made sketches first.

How can these improvements of the surface structure of design activity by sketching be *explained*? In the survey just cited the engineers argued that sketches are not only mnemonic aids but also a kind of thinking tool, assisting them in problem solving. We tried to capture these verbal reports in an experiment. Sixty participants were asked to answer questions concerning the components and the relations between these components of mechanical systems (selected from Larkin & Simon, 1987). The written descriptions of these systems were presented during the session. One group had to make sketches of the system before the questions were asked; the other one had no possibility to make sketches. The sketches were removed before the questions had to be answered.

The results are presented in Figure 10. It appeared that making sketches does not improve the number of correct answers concerning system

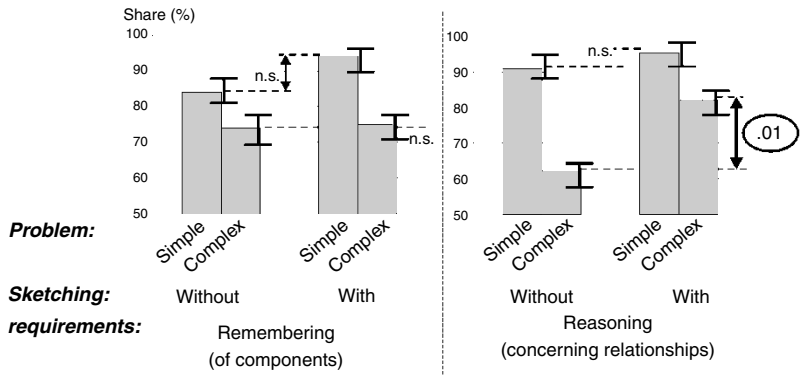


Figure 10. Percentage of correctly remembered system components and relations correctly deduced by reasoning, depending on problem complexity and sketching during the analysis (Sachse, Hacker, & Leinert, in press).

components if it is just a matter of recollecting this information from memory. However, making sketches significantly increased the number of correct responses on questions concerning the *relations between components* within a complex system, which are not presented directly in the description but must be deduced by *reasoning*. As it happens, a psychomotor operation, i.e., sketching, improves thinking, i.e., a mental operation.

In terms of Action Theory, these improvements of innovative performance are determined by the interaction of psychomotor and mental operations that modify the mental representations. This type of finding has *general practical consequences*. Innovative mental work needs hybrid practices with mental *and* physical operations, like manual sketching, writing, impromptu modelling, speaking, or gesticulating. Consequently, modern computer-centred design education must be complemented by seemingly old-fashioned practices (Henderson, 1999).

If *thinking in and by action* is a general principle of innovative mental work, other kinds of psychomotor components of mental work, especially speaking, should offer similar improvements.

Question answering techniques—reflection improving the quality of artefact design. In studies where people were questioned on the sources of innovation, the participants attributed great importance to informal conversations, e.g., in coffee breaks, for idea generation (Figure 11). However, usually it is not the conversation partner who brings up the solution, but often the speaker generates the idea that contains the solution while describing and explaining the problem to somebody else. Thus, speaking with the help of syntax and semantics can help finding the solution.

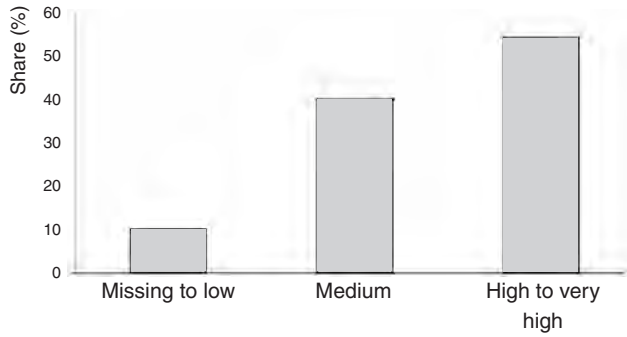


Figure 11. Assessment of the contribution of informal and accidental exchange of ideas to innovations in a company ($n = 47$ companies of different branches) (Wetzstein, Oberkirsch, & Schumann, 2003).

The reason may be that a dialogue, with a real or even a virtual partner, initiates and stimulates reflection.

The notion of reflecting on one's actions is well known (Schön, 1996; Swift & West, 1998; Valkenburg & Dorst, 1998). In Action Theory, self-evaluation of the procedure and/or of the results is a decisive component of executive action control, which has been emphasized since its beginning (Rubinstein, 1984). Already in Vygotski's socio-linguistic approach (first published in 1964) reflection was defined as the transfer of linguistic argumentation from a level of social dialogue into an internal level, i.e., inner speech. Speech is considered to be a social tool for developing high-level cognitive skills. As was already mentioned, Galperin (1967) developed, based on these ideas, the dialectic, recursive or cyclical Theory of Internalization and Externalization of external into internal mental processes, and vice versa.

In a series of experimental studies we were interested in the specific question of whether reflection on one's own solutions, solutions that people *perceived as finished*, i.e., reflection at the very end of a design process, further improves the quality of the solution. The independent variable here is the type of reflection.

All participants had to answer a list of questions that were introduced by question words, such as "why", "what", "how", "which", etc., that required people not only to describe their solutions, but also to provide justifications for their solutions, and to explain and to evaluate their solutions.

Eighty students designed a garden grill. In the first group the experimenter asked the questions concerning the sketches and the participants answered them aloud. A second group received the questions in writing and answered these questions by speaking aloud to themselves.

The third and the fourth groups also received the written questions but answered in writing, the third group having concrete and the fourth group abstract questions. All four groups achieved significant improvements in the quality of their solutions after these interventions. The degree of these improvements did not differ significantly between the groups (Figure 12).

Consequently reflection on design solutions, and more generally on the results of innovative work, can lead to substantial improvement of artefacts (Wetzstein & Hacker, in press). These improvements seem to be the result of a specific dialogue-like type of thinking (cf. Bartl & Dörner, 1998). Thus, enhancing the quality of the solution is the result of cognitively enriched regulation of activity that forces one to infer essential semantic relations in systems, e.g., causal, conditional, or final relations.

If the virtual dialogue with oneself can improve innovative work, what about the impact of real cooperation on innovation?

Hybrid cooperative work vs. the illusion that groups can stimulate creativity. There is pervasive evidence in Social Psychology that people produce more ideas, and more good ideas when working *alone* rather than in groups. As revealed by experimental research on small groups, the idea that groups are more effective than individuals is an illusion that ignores the various types of productivity losses in idea-generating groups (Stroebe & Diehl, 1994). However, there is a discrepancy between this experimental evidence and the beliefs on team work in the business community and even

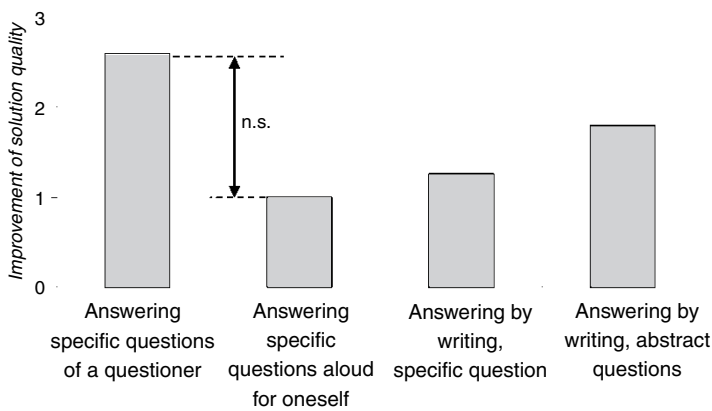


Figure 12. Improvement of completed designs after interventions (difference pre-/post): means of groups and standard errors; all groups improved significantly (each $p < .01$); the improvements do not differ significantly ($F = 1.56$, $p > .05$; Winkelmann, Wetzstein &, Hacker, 2003).

in the community of Work and Organizational Psychologists. Action Theory might offer a solution for this discrepancy.

From an Action Theoretical perspective the crucial variable in any kind of work is the "task" (Hacker, 1995). Actually, Hackman and Vidmar (1970) showed that 90% of the variance of cooperative performance is explained by the kind of the task people worked on.

The type of task of interest here is product development. On the one hand this type of task cannot be solved individually since heterogeneous knowledge domains, e.g., expertise in mechanics and in electronics, are to be integrated into an overall solution. On the other hand, the group cannot continuously work together as a real group, since a competence-based *division of labour* reflecting the heterogeneous expert domains will be more efficient. Thus, the actual question is not whether group work *or* working individually is more effective, but how to *combine* individual work and group work efficiently. Different phases of design or problem solving can profit from different types of cooperation. We, therefore, suggest a hybrid cycle of synergetic types of work with four steps (based on Neubert & Tomczyk, 1986; Tschan, 2000):

(1) The group is jointly instructed and a task-specific group of experts is constituted, and their probably differing task redefinitions and the division of labour are adjusted. This is a *real-group work* step.
(2) The experts work *individually* but with a group mandate to work according to their heterogeneous domains of expertise and to the rules of division of labour.
(3) The partial solutions of individuals are preliminarily put together applying a *nominal-group* technique.
(4) These partial solutions are to be integrated into a complete and final solution, and this again requires *real-group* work.

Is there any practical impact? The added value of this hybrid type of cooperative work is high. In a study on microchip production our group achieved a reduction of the necessary running time by 30% by applying this technique (Table 5).

IDENTITY OF BASIC MENTAL PRINCIPLES: VARIETY OF USEFUL APPLICATIONS

"...a European way of promoting the quality of working life and organisational effectiveness"

The website announcing this Congress stresses as its aim to contribute to a "European way of promoting the quality of working life and organisational

TABLE 5
Increase of effectiveness and its sources by a hybrid cooperative/small group technique (Wetzstein et al., 2003)

	Before	*After*	
	Hybrid cooperative work		*Relative change*
Faultless batches per week	4721	6770	+ 30.3%
Mean waiting time of batches	0.22 days	0.17	−23.3%
Mean running time of batches	0.41 days	0.36	−12.2%
Mean number of faults/batch	1.43	1.04	−27.3%
Mean number of working steps			−24.0%

effectiveness''. Traditionally the typical approach of old Europe is to develop *theories* in order to explain and subsequently to design reality, and these theories are anchored in long-term tradition of classical European philosophy. Imagine for example Adam Smith, Marie Jahoda, George Friedman, Adam Schaff, Ralf Dahrendorf, André Gorz, Kurt Lewin, Sergei Rubinstein, or Einar Thorsrud. Following the philosopher Leibniz, there is nothing more practical than a good theory. Moreover it is a venerable tradition of European work design—recently even based on directives of the EU—to combine effectiveness of work with the quality of working life.

Action Regulation Theory has been a frame of reference for several European research groups, and is a valuable European way of thinking and acting. Moreover, it stresses the identity of a few basic mental principles allowing a high variety of useful future applications.

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