

PEOPLE AND TECHNOLOGY

a cognitive approach to contemporary instruments

LES HOMMES ET LES TECHNOLOGIES

une approche cognitive des instruments contemporains

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**PART ONE: ACTIVITIES WITH INSTRUMENTS,
POSITION IN THE SOCIAL FIELD AND
SCIENTIFIC APPROACHES**

The aim of this chapter is to situate the instrumental approach in terms of the **social fields** concerned (work, education, daily life), and the questions thrown up by the **scientific fields** of psychology, didactics and ergonomics.

The problems faced in the **social fields**, the debates they generate and the contradictions and issues that they touch on, are so vast that an all-encompassing and objective approach appears extremely difficult. However, we will demonstrate that some options, particularly those postulating an underlying elimination of “human components” in production systems, cannot be a pertinent frame for analyzing activities with instruments given that their defining feature is precisely the presence of humans and their activities. An instrumental problematic is necessarily centered on humans and grounded in an anthropocentric option. In removing people from activity, in our opinion, psychology, ergonomics and didactics lose their *raison d'être*.

The positioning in **scientific fields** does not aim to be exhaustive either. It seeks to identify the main approaches to activity with instruments in the psychological field and in fields of action to which it contributes, particularly ergonomics and didactics.

At first, we will define approaches to human activity based on a technocentric view that tends to attribute a residual place to this activity. Points of view criticizing technocentric approaches will then be analyzed, followed by arguments in favor of an anthropocentric perspective on anthropotechnical objects and systems. This latter perspective will serve as a guide to situate different non-psychological approaches to artifacts and techniques. Psychological approaches will then be examined in detail.

CHAPTER 1: FOR A HUMAN-CENTERED APPROACH TO TECHNIQUES

Technocentric points of view on human activity at work

There is a joke that pilots tell each other with half smiles: “in airplanes of the future, there will only be two seats in the cockpit - one for a person and the other for a dog. The dog will be there to stop the pilot touching the controls and the person will be there to feed the dog.”

What lies behind this “joke”?

Activity as a residue

Limiting human intervention, considered inefficient and unreliable, too expensive or too risky, is one of the current trends in the productive system. In this perspective, reducing the place of people, the tasks they perform and the actions they accomplish is an objective. Yet even the ideology that vehicles the complacent image of the operator-free factory does not hide the fact that

today, it is impossible in practice to master everything or have everything done by machines¹. Even in this perspective, there is a place for humans. In airplanes of the future, for example, the pilot (who may or may not still be called a pilot) could be present merely in case of unexpected problems that cause the automated systems to break down. He/she would recover breakdowns and incidents, or perform limited operations for which he/she would remain temporarily more proficient.

The place that this perspective accords people is residual: humans occupy an ever-shrinking place, performing tasks that have not yet been yet resolved technically in terms of reliability, safety, efficiency, performance, usefulness, optimality and automation. As Clot (1992) indicates, "the path that consists in reorganizing tasks with the objective of having the results no longer dependant on the operator - this path that is often taken and that the contemporary strength of machinery allows us to imagine more and more as a desirable option - consists in seeing human activity as a residue." Bainbridge (1982) reminds us that it only leaves operators tasks that are too complex or impossible to automate.

Nonetheless, the "residual" perspective is only one of the possible options and must be situated historically. For Millot (1991), automation initially aimed to give system procedures commands to make their operation fully autonomous. Operators were retained in order to carry out decision-making supervisory tasks that were not yet automatable. This analysis is in line with that put forward by authors like Brodner (1987) or Craven and Slatter (1988): "designers predominantly adopted a technocentric approach in the design of man-machine systems, concentrating their efforts on the efficiency of fixed capital and tending to ignore human factors."

However, according to Millot, the initial concept of automation excluding operators then evolved toward a concept aiming to reintroduce them into the automated system, but in considering them as a "necessary evil" whose errors have to be limited. Millot claims that today it would be possible to move beyond this stage with decision-making assistance tools. These would allow operators to intervene early or in anticipation of incidents. He thus concurs with theoretical analyses based on the empirical results of Roth, Bennet, & Woods (1987). These results affirm the possibility of developing technical systems that are not only prostheses that compensate for operators' shortcomings but on the contrary, are instruments at their service.

A pessimistic view of human intervention which leads to a strict delimitation of activity at work

The "residual" point of view corresponds to a pessimistic view of human intervention. David Noble (quoted by Bernoux 1991) maintains that the digital control of machine tools was chosen over another option in which "the programming was not designed by engineers sitting at their desks but by the

¹ The crucial question of the pertinence and social legitimacy of the productive system opting for a progressive reduction of operators will not be discussed here. It goes without saying that this dimension of the problem is essential in a period of increasing mass unemployment.

production workers who operated the machine and programmed the new tasks it had to perform, i.e. programming while doing". According to Noble, the digital control option corresponds to a pessimistic view of human intervention as a source of errors in the production process. The second option, on the other hand, would have called upon the operators' competence and judgement. This point of view is shared by Johnson and Wilson (1988): "designers mostly consider the human operator as an inefficient and unreliable systems element".

In the residual perspective, it is not only the room for human activity that is restricted. The nature of the activity, given the pessimistic point of view, also tends to be strictly delimited. Spontaneous human interventions are considered likely to disrupt, or even damage, the operation of expert automates and machines.

In our "joke", the dog is the emblematic figure that represents the "necessity" of forbidding misplaced initiative or disruptive action. At the very least, it must be channeled and sufficiently controlled to render it inoffensive. In the design of airplanes, for example, Gras & Scardigli (1991) highlight the increasing number of systems that aim to prevent excessive accelerations, tilts or turns, i.e. any departure from the norm or personal piloting style. The tasks attributed to the pilot are reduced to a minimum.

Technological choices of controlling and delimiting activity correspond to the pessimistic vision of human intervention.

An example of a technocentric point of view

These options are in line with fundamental technological research choices that also accord a residual position to human activity. Thus, Sacerdoti (1977), in a publication about planning in Artificial Intelligence, looks at the design of robots that seeks autonomy. Convinced that robots' means of perception will remain rudimentary for a long time to come, he attempted to design machines paired with a human operator, with constant interaction between the user and the system. His perspective is the design of machines for which humans are an essential supplement given the current and probable future insufficiency of technological knowledge (in this case in terms of artificial perception). The departure point for Sacerdoti's research problematic is the technical system that incorporates people as supplements for that which is not yet treatable by technology. People are not the focus of this point of view. They are constituted in reference to a predominant technological point of view. For this reason, this type of problematic is technocentric.

How pertinent are technocentric and anthropocentric points of view?

Two main perspectives are thrown up by this first approach:

- a predominantly **technocentric** approach in which humans occupy a residual position, and in which their real activity no longer has a specific status. It can thus only be considered in the same terms as a technical process. As the work philosopher Schwartz (1988) put it, when we apprehend

work only by its technical nature, then there is no other solution than to speak of people via things, even when this option is grounded in a humanist perspective;

- a predominantly **anthropocentric** approach in which humans occupy a central position and determine the way relations with techniques, machines and systems are seen. This option places human activity at the heart of analysis and thus allows the reversal necessary so as to speak of things in terms of people – to use Schwartz's expression.

Of course, neither of these two points of view is sufficient in itself. The technocentric approach alone tends to place humans in a residual position and cannot allow a true apprehension of their activity. However, a unilaterally anthropocentric approach is incapable of apprehending technical systems in their technological specificity. The answer clearly does not lie in negating one of these approaches (which constitute poles at either end of dozens of intermediates). Rather, it is in their conceptual and pragmatic conjugation allowing the apprehension of a production system from both technological and human activity perspectives.

Yet today, conceptualizations of people's place in terms of their activity are insufficiently developed, or in any case much less so than technology-oriented ones and are sometimes even caricatured copies of the latter. The activities with instrument approach is one way of compensating for part of this deficiency and making up for lost time.

Through criticisms of approaches that are too unilaterally technocentric, we will see that the development of anthropocentric conceptualizations appears to be necessary, perhaps even urgent.

Criticisms of technocentric approaches

Many criticisms have been leveled at design in which people are considered as residual to technique. Lack of space obliges us to consider only a small number of these. We will focus on the field of work activities and those thrown up by psychology and ergonomics (control of operator-computer processes and interactions), as well as critical social theories.

Process control

Making industrial processes reliable is an important issue today given the economic, human and ecological costs of accidents and incidents. Several studies carried out in this perspective have attempted to determine the origin of errors usually considered as "human". They lead us to reconsider the origin of a number of these errors. For example, Reason (1990) demonstrates that some errors considered as "human" are in fact linked to causes deeply rooted in technical systems in the same way as pathogenic agents exist in a human body.

The nature of tasks entrusted to operators in automated procedures also throws up questions. In his revealingly titled text “Ironies of Automation”, Bainbridge (1982) notes that the progressive elimination of humans in favor of robots paradoxically leads to only entrusting operators with the group of miscellaneous tasks not based on the needs of their activity but based on what is not automatable.

In the aviation field, debates on the place and the role of pilots in new generation airplanes are also heated. As of 1980, Wiener & Curry suggested that the pilot be “reintroduced” into the piloting circuit but in an “envelope” placed under the system’s control. Thus they considered that the pilot had indeed been removed from the circuit!

Morishige (1987) who along with Rouse, Geddes, and Curry (1987) argues in favor of an approach to automation centered on the operator, also disputes the efficiency of the “full automation” option. For Morishige, who has developed studies in the field of fighter planes, the performance of automated systems is liable to improve when technical devices supply appropriate information to pilots. However, as the curves on the diagram indicate (figure 1), overall performance tends to worsen when automation is increased (when the system provides solutions or when it exercises control alone with no “manual” intervention). The author does not present empirical results to support this theory but its radical nature indicates the scope of questioning in this field.

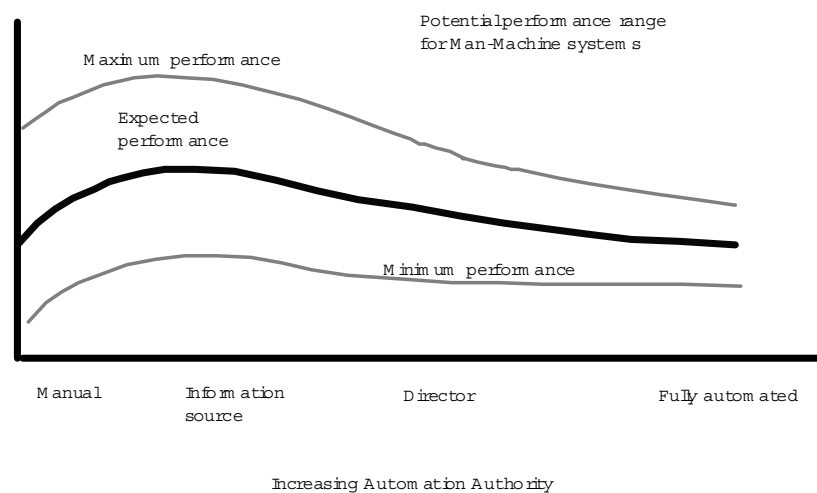


Figure 1
Performance of a human-machine system in the automation of airplane cockpits (based on Morishige 1987)

Human-computer interactions

Likewise, in the field of human-computer interactions, Kammergaard (1988), in agreement with Ehn & Kyng (1984), considers the excessive influence of the “system” perspective as a serious problem in the development of application programs: many of the negative consequences of application program use in the workplace are due to insufficient attention being paid to approaches centered on people at work

The system perspective, which is widespread in software design, is considered insufficient by these authors because operators are seen as equivalents to other components of the system: a group of human and machine components performs tasks as a result of their interconnected actions. Thus the task does not have a specific expression on the individual level. In this perspective, interaction is considered as a transmission of data between human and software components. This transmission must be effective and efficient (this is the main quality of the interface). For this reason, the user must if possible follow modalities similar to those of the machine.

Designers thus see standardizing the interface and disciplining the user as good solutions. Studies based on this point of view aim, first of all, at making data transmission faster and more reliable. The main design problem is then the distribution of tasks between user and machine for data processing.

Our authors consider that this perspective reduces human work to a data processing activity that is the only one capable of conceptualizing, in a technocentric perspective, in terms of algorithmic procedures. Breaking with this technocentric approach, the Utopia project (with Kammergaard's participation) was developed so the user could have a view of the system in which people, machines, tasks and materials are seen as interconnected in a terminology founded in the realm of tasks significant to the user.

Critical social theories

The discussion of the residual perspective and technocentric options are of course grounded in critical social theorists and sociologists such as Haudricourt (1964 & 1987), who calls for technology that would at last be a social science, or Habermas (1968) who conducts a powerful and stimulating critique of what he calls instrumental cognitivism.

Lhote & Dulmet (1992) consider that reference to human work is essentially missing from engineering science research (optics, electronics, electrotechnology, mechanical and procedural engineering). According to the authors, it is only in industrial automation that a partial awareness of the impossibility of eliminating human work is emerging. The production systems studied here are fundamentally hybrid, i.e. made up of human and technological resources. How these systems evolve throws up the “question of how to define the new role of humans in systems that are highly computerized and automated”. Work must take on a central position in

engineering sciences because, according to the authors, the specialists of these disciplines must recognize:

- that the user is omnipresent as soon as we stop focussing on objects that are too intermittent and the direct interventions they support;

- that the dream of the operator-free factory becomes a nightmare as soon as we realize, beyond its unacceptable social cost, the inescapable limits of purely computerized or automated solutions in terms of flexibility, reliability, adaptation to change, reactivity to hazards: purely technical approaches cave in under the weight of the complexity, cost, development time and question of efficiency when we consider systems thrown into the unstable and changing environment that currently typifies most companies.

Criticism of the residual perspective also comes from administration and company sciences. For Freyssenet (1992), belief in the possibility of replacing work or fully controlling it is a denial of reality. Engineering and administration sciences are starting to realize that the increasing number and sophistication of technical and controlling devices and attempts to understand the adaptability and inventiveness of the work act have led to burn out. According to the author, today these fields as well as certain companies are asking themselves:

- how to define a technical system in which the worker would not be the weak link in the efficiency chain but on the contrary, an actor of increased reliability, performance and development;

- how to define administrative tools that are not prescriptive, but rather aids for work collectives² in conducting action.

We can only concur with Freyssenet's conclusion: the irreducibility of the work activity has been heightened precisely because principles of substitution and reglementation have been taken so far.

The activities with instruments problematic is part of the movement that criticizes the perspective that reduces human activity to a residual position. It seeks to contribute to a predominantly anthropocentric design of technical systems that are truly centered on an operator who is an actor of his/her work and therefore, an actor of the reliability, development and performance of the technical systems he/she participates in. Thus these systems must be considered both as a means of production (in the broad sense) and instruments for people at work.

Towards a human-centered design of techniques

² Recent developments in administration science are in line with this. They seek less to identify costs than to ensure that companies possess and can mobilize competence to produce economic value (Hubault & Lebas 1993).

The critiques that we outlined above come together to question approaches in which the place of people at work is seen in reference to and by its difference from that occupied by the technical system, i.e. in a residual perspective and often in the terms of the technique itself. Dubois P. (1992) insists that since the myth of the operator-free factory has done its time, relying on people to improve technical performance has become essential.

Another view of human relations with systems is emerging. In this view, technical systems and machines are considered in terms of operators and not the contrary. Humans are central and the place of technology is defined in relation to them. In this view, the technical system is centered on the person who is to use it. It will be imagined, designed and created in reference to the user (or users) for whom it will be a tool or an instrument. An anthropocentric notion of technique such as this is necessary and awareness of this necessity is starting to emerge, as we will see, in a variety of research and action centers: in companies, in training, in ergonomics, and in research policies.

Quality as a factor for re-centering on people in companies

Some of the current changes in criteria that production is subjected to are in line with a re-centering on people. While productivity and cost criteria have obviously not been abandoned, new criteria are being implanted. This is true of quality criteria, which lead, in some cases, to a reexamination of the place of people in the productive system. Of course, some undertakings favor a predominantly technocentric approach to the problem by assuming that a full control of production systems requires repeatability, as is sometimes the case in quality certification operations. The human activity point of view is then difficult to impose as Christol and Mazeau (1993) point out: the risk is that formalizing operations degenerates into a normalization that is seen as an end in itself: this return of the "one best way" is of concern in that one of the limits of Taylorism was precisely its difficulty in obtaining quality. Complete mastery of the production system only through repeatable procedures appears more and more as an unrealistic objective. Quality results from a system including: heterogeneous raw materials; equipment of varying reliability; organizational rules that must be interpreted to attain efficiency; men and women who are different from each other and whose characteristics change constantly, Deltor (1993). This is why anthropocentric approaches that consider operators as producers of quality and in some cases, as the main producers of quality are developing in certain companies.

Technical training and professional didactics

Meanwhile, in technical training, a renewal of interest has been observed for dimensions of professional competence such as skills, whose role in the operation of contemporary technologies had hitherto been underestimated or denied.

For Deforge (1991), both actor and observer of changes in technical training in France, two trends have shaken this field since its foundation in 1919:

- a movement toward grouping activities into branches based on the rationalizing and unifying ideology of technological training which has always aimed to surpass and erase technological particularities through reason. This rationalizing impulse, which was very strong until recent years, opposed notions of skill and assumed it would only persist in trades destined to disappear.

- a centrifugal tendency that despite a desire for unification, brings out corporative subdivisions or those inspired by the operational constraints of professions..

Technical training has fought hard against skill, testifies the author who participated in this battle as an inspector. Yet, he says, today it is coming back to other options and considers that skills have their place in the most evolved industrial processes. For Deforge, the efficiency of skills allows models born of technology that are too far removed from reality to reduce this distance. He considers skills as a specific source of qualification and a bonus for companies.

The revival of skills in the education system's training programs occurs primarily through on-the-job training courses, retraining courses and school-workplace schemes. We feel this is partly because changes in the recruitment of teachers has brought about a partial loss of the education system's training capacities in this field.

Originally, teachers of technical training courses were experienced professionals, preferably the best in their field. Today, they are mostly graduates in technical training whose trade experience is sometimes limited to a few brief sessions of work experience.

The demand for professional experience tends to be replaced by demands for technical knowledge as Tanguy (1991) indicates. The consequence is a distancing from the work activity, which then determines the recruitment of teachers and makes professional training of students more difficult. We are not convinced that the current move toward a range of training-workplace relations, work experience programs and the extension of training to the highest levels of education will fully compensate for the problematic effects of the excessively technocentric options followed in French education.

The current emergence of new research perspectives aiming to construct professional didactics is in line with Deforge's conclusions (1991): technology as a technical science allows us to understand techniques. However, when we have to perform technical acts in a technical environment, technical science is not enough because underlying techniques is the human actor with his/her skills, personality and affectivity which, he concludes, is so much the better.

We can hope that professional didactics (a supplement to technical didactics), initially focussed on professional training in professional environments, will also contribute to an anthropocentric revitalization of technical training.

Ergonomics and anthropotechnology

The ergonomic approach, a minimal definition of which is work's adaptation to people, is grounded in a predominantly anthropocentric approach and has been since its inception.

We will not go into the methodological, conceptual and theoretical evolutions in this field. Let us note only that beyond an ergonomics of human factors (sometimes known as "tables and chairs" ergonomics) based on analyses in terms of human "properties" that must be considered in a work situation, another form of ergonomics has developed. Influenced by the French-language school, ergonomics centered on human activity in the workplace has integrated and moved beyond approaches in terms of human factors. Today we see the emergence of predominantly cognitive approaches that aim at treating more specifically the cognitive dimensions of activity, in particular in connection with contemporary changes in work and the massive implantation of information processing machines (see, for example, Green & Hoc 1991, Hollnagel 1991, Thon & al. 1991, De Keyser 1991, etc.).

Thus, in the field of research into interactions with machines and information processing, Floyd (1987) distinguishes between two paradigms corresponding to two possible points of view in a design or research perspective:

- a paradigm defined as being product or machine-oriented; a point of view described as traditional in which the user is considered as static, with a fixed interaction with the machine that is pre-determined within the machine;
- a paradigm considering computers as tools for people doing a real job;

The author favors this second point of view centered on usage processes. He calls for an extension of the notion of the user. He writes that we must move toward design that considers the user as a person performing a real job.

Likewise, for Bannon & Bodker (1991) artifacts must not be analyzed for themselves and in isolation. They must be analyzed in their use settings which are non static, and evolve and develop over time. For this reason, a historical view of technology is necessary.

These reflections and analyses centered on the use of computer tools led to research into design practices which are themselves anthropocentric. A good example of this is the book by Norman & Draper (1986) "User centered system design: New perspectives in Human Computer Interaction"

The necessity of developing anthropocentric points of view has also emerged in the field of production systems. Clegg (1988) puts forward the idea of users appropriating the design of advanced production technologies. This appropriation perspective should be understood as having a double meaning: problems and solutions should be appropriate to users in that they need to be adapted to them, but also in the sense that they should become, in a certain way, their property.

The option of an anthropocentric approach to production technologies is developed by several authors in an ergonomics perspective. Corbett (1988), who places its origins in the studies developed in the late 1970s, resumes five main characteristics based on the literature:

- the anthropocentric approach is based on existing user competence and seeks to develop it, whereas a conventional approach tends to incorporate it into machines, thus contributing to a de-qualification of operators;
- anthropocentric technology seeks to increase the degrees of operator freedom to allow them to define their own work objectives and activities. Operator control precedes that of technology;
- anthropocentric technologies aim at reducing the division of labor;
- they aim at facilitating social communication (formal and informal) among operators;
- and more generally, they must aspire to the development of working environments more compatible with work health, security and efficiency.

Beyond these developments of ergonomics centered on the work situation and more generally on activity, the necessity of expanding the field of ergonomics has become apparent. The concept of macro-ergonomics including organization and training put forward by Hendrick (1987) joined studies on the industrialization of newly independent countries (Chapanis 1975, Seurat 1977) and the anthropocentric perspectives developed by Wisner (1976, 1985) to look at the problem of transferring technologies to developing countries whose economic, climatic, organizational, cultural and more generally anthropological conditions are different from that of the country from which the technology originated. However, as Montmollin (1992) indicates, while macro-ergonomic approaches correspond to real problems, today their theoretical grounding is often hazy and eclectic, closer to ideology than a truly scientific approach. A huge theoretical undertaking remains urgent in this field.

The anthropocentric approach to human relations to technology thus moves beyond the situation of an individual in the workplace to consider the collective dimensions of work and the anthropological specificity of human groups on a worldwide scale. This does not undermine its relation with the subject using tools he/she must appropriate in new conditions, as Guillevic (1990) reminds us.

Research policy inclinations

The necessity of an anthropocentric development of techniques is also reflected in the analyses and recommendations of European research policies.

Cooley (1989) states that current systems are predominantly designed in a technocentric perspective. According to the author, they tend to render

users passive and the machine active. They are born of design dominated by the three essential characteristics of natural sciences (predictability, repeatability and mathematical quantification) and tend to exclude intuition, subjective judgement, tacit knowledge, imagination and intention. The author sees this as the result of a trend toward marginalizing operators and turning them into passive appendages to the machine. Based on his thesis, he reminds us of the suggestion formulated in an article from "American Machinist": the ideal worker for most digitally controlled machines would be mentally retarded with a mental age of 12.

Nonetheless, as Martin (1989) stresses in the same report, all attempts at designing digitally controlled machines with no need for operator competence have failed. Despite a partial automation of operations, the skills and knowledge relative to production remain indispensable to use these machines efficiently. This is why systems based on an exclusively technocentric approach encounter serious difficulties: they are not very robust or flexible and are extremely sensitive to disruptions. The authors conclude that it is necessary to develop anthropocentric technologies that associate human skills and ingenuity with advanced and appropriate forms of technology in a true symbiosis.

Among the research fields that this report targets for development is the design of anthropocentric systems and tools as opposed to machines. In the education field, it also recommends studies on training methodology through use in the field of new technologies, as well as the elaboration and generalization of knowledge in training through action.

Conclusion: techniques must be considered in terms of their psychological dimensions

In a publication aiming to constitute technology as a human science, Sigaut (1991b) highlights the strangeness of the belief that techniques are not social: once this belief is overcome, techniques return to the fold of social sciences.

In the same way, it seems to us that the idea that techniques are not psychological is every bit as strange: techniques must also join the problematics of psychology and two main directions seem possible.

- One of these directions consists in apprehending the operator and machine in the same terms. Today, this is a well-worn path, particularly in the field of cognition. It sometimes seems that the limits of the mechanical metaphor are not always well defined or mastered.

For Feigenbaum (1991), thought is of the same nature, whether it be human or mechanical. "Humanity is a mechanism," he says. According to him, the nature of the physical, material incarnation that supports thought is of no importance because thought can be reduced to the manipulation of symbols. "What is the importance of physical incarnation? What difference does it make that we are made up of flesh and blood... Do we wonder what sort of body Einstein had? We never think about it when we refer to the general theory of relativity," states the author.

Onfray (1991) gives us a timely reminder that these theories are not new. Oscillation between understanding humans as machines and constructing machines that simulate them goes back a long way. Already in the 16th century there was a twin approach in which the body was seen as a machine and machines simulated the body (giving rise to the success of robots). Descartes, for example, dissected animals, and perhaps humans, and at the same time tried to develop robots.

We can wonder whether Feigenbaum's statements are perhaps contemporary forms of an update of this perspective in cognitive terms. Perhaps tomorrow, we will smile at the over-simplicity of his affirmation, just as today we smile at the hypotheses of 16th century mechanists or the fantastical (and no doubt provocative) predictions of Minsky: artificial intelligence, that of machines, will soon be so developed that we will be lucky if computers allow us into their homes as pets. It seems that these predictions are taking a long time to come true. Perhaps it is because fundamentally speaking, computer processes and thought and human activity processes are definitively non-interchangeable.

- Another direction consists in trying to apprehend machines and humans in different terms, not making them interchangeable, and analyzing technical activities in human terms. It is in this perspective that the instrumental approach we will develop in this publication will be grounded.

Technique is the way someone does something, wrote Lynn White in a phrase whose importance, according to Sigaut (1991), is to remind us that the "someone is essential" because he/she indicates the right perspective. A technique only exists when it is practiced, i.e. when it is passed via someone who, having learned or invented it, applies it efficiently. There is no technique without efficiency and the human skills it implicates. Techniques must thus be observed where skills are produced. However, this always takes place on a scale of one or two individuals. The observable reality of technique is on the scale of a person or a small group of people.

We can only adhere to this conclusion. Even if analyses must be situated at different levels, we share the author's point of view that the best level is that where there is direct contact between operators and material objects - we would add, more generally, between operators and the objects made as well as artifacts (including symbolic ones), and their associated uses. This analysis scale is precisely that of psychology even if it is not exclusive to it.

The instrumental approach is thus situated on a level of analysis of techniques as psychological constituents. It contributes to theoretical reflection and the empirical examination of relations between humans and human-centered technical systems from the perspective of operators engaged in real activities and actions situated in their work, training or daily life contexts.

Advantages and limitations of non-psychological approaches to techniques and artifacts

The development of points of view relative to human-centered technique requires theoretical and methodological tools fitting with these goals. We share the view of Hatchuel (1992) who calls for an enrichment of the analysis of technique. In order to do so, he says, we must ground ourselves in intermediary theories that are not paraphrased from the language of the mechanic, robot technician or chemist, nor simple discourse on social arrangements. According to the author, notions such as tool, instrument, procedure, prototype, machine, assembly, construction and integration are already intermediary notions that we use spontaneously but they are fragile.

Social actors mobilize particular knowledge that depends on the relations they build with technical objects: their intentions, use and fantasies. The idea that an object has a use is, according to Hatchuel, an excessive simplification: a technical object has uses that our knowledge allows us to apprehend or discover; we must recognize that a particular object can be compatible with several types of technical knowledge and thus also with several types of technical competence. In exploring possible categorizations of knowledge, we look at technical objects in a way that permits us to reconstitute the nature of relations an actor will have with them, as well as the validity and legitimacy of his/her actions.

Gonod's approach (1991) aims to clarify these relations. He puts forward a global vision of the rationales underlying our relations with technical artifacts (figure 2). The author distinguishes four rationales: construction, operating, use and evolution, based on which he situates approaches by different scientific disciplines (figure 3). This approach is interesting for its attempt to situate and coordinate possible points of view. However, in its current state, it is still insufficient: consideration of human activity is limited which leads, as we can see in figure 3, to an absence of any reference to psychology as a discipline allowing analysis of technical constituents. It is thus necessary to complete Gonod's synthesis:

- in taking figure 2 as a starting point, we must at very least add a design rationale corresponding to designers' activity (and thus in relation with – but distinct from – the construction rationale) and give a psychological sense to the other dimensions, particularly to the utilization rationale;

- add the missing family of disciplines (psychology, ergonomics and didactics) to the approaches identified in figure 3.

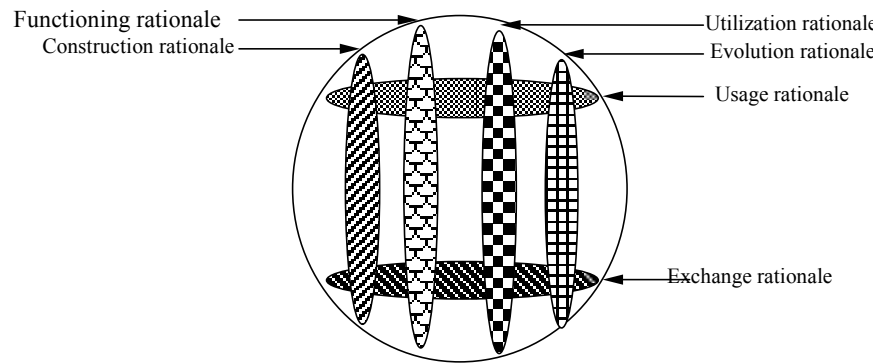


Figure 2

Multidimensionality of technology (based on Gonod 1991)

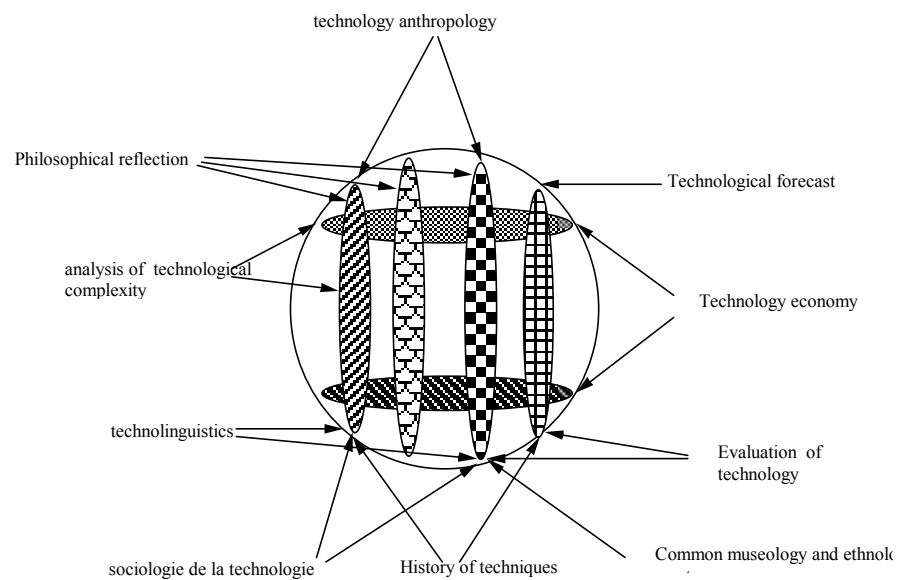


Figure 3

Multiplicity of scientific approaches to technology
(based on Gonod 1991)

Perrin (1991b) takes a step in this direction: he criticizes the point of view that sees technology as an application of sciences. He says we must distinguish between the knowledge processes of natural sciences and artificial sciences.

According to the author, the history of engineering sciences (civil, mechanical, chemical, etc.) indicates that they have only made progress when confronted with the design and construction of new artifacts. The production of technical knowledge is fully linked to that of artifacts: the action of designing a new technical object engenders the process of transforming and producing technical knowledge. Affirming that artifact design activities give rise to the production of technical knowledge means accepting that the

production of technical knowledge is based on specific characteristics of these design activities.

It also means hypothesizing that the laws of evolution and genesis of technical objects result from characteristics specific to intellectual and organizational procedures that are used in designing them (Perrin 1992).

In the point of view developed by Perrin, a part of human activity appears: that of designers, and this is very important. Yet it is limited to the sphere of artifact design: there is no production of technical knowledge in use. Thus the utilization sphere and the associated knowledge production processes (knowledge and representations for action) remain unrecognized.

Affirming that technical knowledge can only progress via the design and construction of new technical objects again indicates a point of view that is partly technocentric in which technique is reduced to objects and systems and only the activity of designers who are socially recognized as such is taken into consideration.

Perrin's position could take on another meaning if the idea of design itself had another meaning: design continues in use, through uses like the design of these uses as well as by a questioning of technical objects themselves. Following this other point of view, usage also gives rise to the production of technical knowledge, particularly knowledge relative to artifacts as instruments.

The instrumental approach aims to contribute to the elaboration of intermediary concepts and theories whose importance is highlighted by Hatchuel. Based on the study of the instrumental relations subjects have, during action, with artifacts, we gain a deep understanding of one of the forms of relations with technical objects: use relations. We will analyze these relations as they are constructed by the subject and in their meaning for the subjects themselves, i.e. from an intrinsic point of view. This undertaking implies distancing ourselves from conceptualizations born of technical knowledge and elaborating and developing the necessary intermediary concepts.

We thus fall in step with authors such as Bannon and Bodker (1991). These authors affirm that since artifacts exist in the activity and are constantly transformed by activity, they should not be analyzed as things but as usage mediators. Artifacts are not only individual means. They are bearers of the division and sharing of labor and their significance is incorporated in social practice. As a result, artifacts evolve constantly and reflect a historical state of users' practice at the same time as they model this practice. For Bannon and Bodker, a computer application program, for example, must be considered as a group of tools whose design creates new working conditions for both the individual and the collective. The introduction of the artifact changes not only the operational aspects but also all the other aspects of the practice. This is why utilization processes need to be at the heart of research rather than the artifact itself.

It is in this perspective that we put forward a psychological conceptualization of artifacts as instruments. We aim to make this conceptualization equally pertinent for ergonomics and didactics. In maintaining links between conceptualizations generated by technological, anthropological, sociological and philosophical fields, we will define the instrument in the essence of its constituting relation: **the subject's use of the artifact as a means he/she associates with his/her action**. The point of view adopted will be that in which machines, technical objects, symbolic objects and systems, i.e. artifacts, will be considered as material or symbolic instruments.

CHAPTER 2: PSYCHOLOGICAL APPROCHES TO TECHNIQUES AND ARTEFACTS

Awareness of the necessity of an instrumental point of view on techniques and, within these, on artifacts, is not a privilege of our era of "new technologies". We will outline the main ideas on the subject. Its history is already long, though somewhat chaotic, made up of forward leaps and sometimes long halts. We will see that today, for many people, a renewal appears desirable.

Vygotsky, a founding vision still alive today: the instrument at the heart of the development and functioning of the psyche

Vygotsky is one of the most profound and influential of authors. Many of the authors we will quote place themselves within, or find themselves one way or another following one of the directions he opened up during what Rivière (1990) rightly called a prodigious decade of production from 1924 to 1934. Vygotsky himself, as Bronckart (1985) reminds us, situated himself within the perspectives explored in philosophy, particularly by Spinoza, Hegel and Marx.

In a text from 1931, he develops the epistemological grounds of his psychological approach. The behavior of the contemporary, culturally evolved adult is the result of two different processes of psychic development. In phylogenetic terms, there was a process of biological evolution which led to the appearance of homo-sapiens, as well as a process of historical development through which primitive man developed culturally. The difficulty of studying superior psychic functions lies in the fact that these two dimensions of biological and cultural evolution, in ontogenesis, fusion into a process that is both unitary and complex.

According to Vygotsky the two fundamental forms of cultural behavior are the use of instruments and the human language. As Verillon (1988b) stresses, we find in Vygotsky what we do not find in other authors that share his preoccupations on the specificity of human cognitive development in interaction with artifacts: an attempt at describing the psychological processes by whose intermediary such a development would be possible.

This attempt places activities with instruments at the heart of the problem of the constitution and functioning of superior human psychic functions. In 1930 based on the notion of interior technique developed by Claparède, he put forward an instrumental method for psychology grounded in the principle of a similarity between the role of “psychological instruments”, seen as “artificial adaptations” that aim to control human psychic processes and the role of instruments in the workplace.

The integration of the instrument in the behavioral process activates a whole series of new functions linked to the usage and control of the instrument. It replaces and renders useless a whole series of natural processes whose work is developed by the instrument. It transforms the progress and the particular aspects of all psychic processes that enter into the composition of what he calls the instrumental act. It replaces some functions with others, recreates and reconstitutes the whole behavioral structure, just as the technical instrument completely restructures work operations. Taken as a whole, the processes are a complex, structural and functional unit oriented toward the solution of the problem raised. They are coordinated, and during the activity defined by the instrument, form a new complex: the instrumental act. Thus, just as work, as an activity adapted to an end cannot be satisfactorily explained in limiting ourselves to goals and problems, the explanation must refer to the employment of tools; the explanation of superior forms of behavior is that of the means that allow people to master the process of their own behavior (Vygotsky 1934).

Because of the in-depth studies he carried out on language in an instrumental perspective, Vygotsky's studies exercised and still exercise a great influence on psychological studies in this field (Wertsch 1979, 1985; Bruner & Hickmann 1983, etc.). However, it is also clear that this same instrumental perspective is destined to have an increasing influence in the field of study and design of relations with artifacts and techniques. For example, Vygotsky is quoted as a reference in five of the fifteen chapters of a collaborative publication postulating the importance of re-grounding psychology in the field of human-computer interactions (Caroll 1991a). This influence is likely to increase, particularly given that an unpublished manuscript specifically treating the instrumental approach, “the Instrument and the Sign in Child Development” has been discovered (Zazzo 1989) and its publication announced³.

Techniques constitute the human environment and are the means of transmitting the species' cultural capital

Leontiev's approach follows the perspectives opened up by Vygotsky and presents them in his articles (for example Leontiev 1965) and two of the books published in French (Leontiev 1975 and 1976) including “The Development of the Psyche”, which is an elaborate synthesis based on several texts and articles.

³ It will be interesting to compare this work with the text published under a similar title in the book “Mind in Society” (Vygotsky 1978).

The relation to artifacts and instruments is an important dimension of the theoretical frame. Leontiev takes up Vygotsky's hypotheses concerning the reconstruction of the activity in use as a whole without, it would seem, contributing anything truly new. His contribution is relative to both a systematic development of the concepts of activity theory and a conceptualization of the notion of the artifact in relation to the development of the human psyche, although here too he takes up Vygotsky's reflections. We too will insist on this last point.

The distinction between natural objects and artifacts is not necessary for a theoretical elaboration of the development of the animal psyche, yet it is for that of humans. When an animal uses a tool, even one that is man made, the animal considers it as part of its "natural" environment that it must adapt to. The animal only sees the tool as a natural means of acting on instinct, for example bringing a piece of fruit closer to itself. The monkey's tool performs a certain operation but this is not fixed in the tool. As soon as the tool has performed its function in the monkey's hands, it loses all interest. It has not become the permanent support for this operation.

It is not the same for human instruments, which are part of the non-natural world produced by human culture. The instrument is not only an object with a specific form and determined physical properties. It is above all a social object whose use modalities are elaborated during collective work. It is a bearer of work operations that are crystallized in it.

This is one of the central points of Leontiev's theory: the fixing of the human species' cultural capital. While the evolution of animal species is biological, human evolution takes place through the fixing of the species' cultural capital within phenomena external to material and intellectual culture.

Each person acquires truly human capacities by appropriating this cultural capital. Leontiev stresses that even instruments or tools from everyday life must be actively discovered in their specific qualities. Users must perform a practical or cognitive activity on these tools that adequately corresponds to the human activity they incarnate, i.e. one that reproduces the characteristics of the activity crystallized (accumulated) in the object.

However appealing this theoretical approach may be, no empirical element has really supported the appropriation thesis besides a few didactic examples. Leontiev leaves us hanging. However, we will see that he is not alone in his cultural approach to the human psyche and the place of artifacts and techniques.

In several texts, Wallon (particularly Wallon 1935, 1941, 1942, 1951) examines relations between people and techniques. He formulates hypotheses on their possible effects on the development of children and more generally, how cognition can be affected or even transformed.

Children cannot be apprehended outside the environment in which they grow up and which is part of them from birth. The world they must adapt to, on which they model their activity and impressions is not invariable and eternal. The group of objects specific to this period: their cradle, their bottle,

their blankets, fire, artificial light; later the furniture whose structures they manipulate, the tools that form their habits and teach them to make things, techniques of language, explanation and comprehension that regulate their thoughts in imposing on them, via conceptual or logical frames, the division of efforts and the objects that inhabit the world placed at their disposal today by thousands of years of material and mental elaboration.

Thus the environment that children react to is not only physical. It is the environment humans have created through their activity. The younger children are, the more they depend on this social environment. Techniques, artifacts and instruments are, like language or customs, constituents of this social environment by which, according to Wallon, people in transforming their living conditions, transform themselves.

Based on the idea put forward by Langevin, that the notions we use to represent familiar things spring from an ancestral and distant contact with them, Wallon explores their evolutions in terms of those of the technically structured environment: what will happen to the notion of human presence, i.e. the possibility of assigning a single spatial quality to combined visual and aural impressions, for a child in front of a radio? It is impossible that the airplane, with its fast contractions of space, will not modify the time-space relations elaborated by people whose measure was their footsteps and the movements of their herds. Speed thus apprehended in its extreme variability could render time and space relations more concrete, more lively and more intimate.

Wallon's examples are dated but the questions he raised over 50 years ago have remained pertinent and important in a period that is seeing, for example, the emergence of "virtual realities". His investigations have profound psychological implications and we can only be struck by their similarity with very contemporary problematics relative to categories of knowledge and its situated nature⁴ (Dubois 1991, Rosch 1975, 1978, Weill Fassina, Rabardel & Dubois 1993) and at the same time to artifacts (in the broad sense), to techniques, and to instruments as psychologically significant objects

He considers that the formula of knowledge categories cannot be considered as given once and for all. They accompany human activity in its ability to use things. They reflect the laws and structures that our techniques allow us to discover and apply in nature.

Human and animal techniques: breaks and continuations

Vernant (1987) reminds us that one of the major ideas of historical psychology developed by Ignace Meyerson is that people must be studied where they have invested the most: what they have made, constructed, instituted and created to edify the human world is their truly natural place: tools, techniques, languages, institutions, literature, arts, etc.

⁴ Knowledge is situated in that subjects strongly associate it with the situations in which they constructed and/or used it. These situations are both dependent on the subject's specific history and that of the society and culture in which it is inscribed.

For Meyerson (1948), the instrument and the machine throw up several problems for psychology, among which is the fact that new techniques act on and form users. Faced with a tool, people can be masters or merely cogs. They can feel more or less dependent. They can participate more or less and in various ways in the machine.

Human objects, “artifices” as he calls them, thus constitute the mediating worlds that form the successive screens between people and nature. Every new technique has its source in and is accompanied by a new mentality. Every invention, however unimportant, acts on people’s minds.

The impact of activities with instruments, and more generally of techniques, on humans is thus designated as an important object for psychology, in particular and not exclusively work psychology given that Meyerson considers work not only as conduct but even more fundamentally as a psychological function (Meyerson 1948, 1955).

Although he did not establish the link himself in his texts, how can we not see in his conception of human psychology, the echo of studies done much earlier with Guillaume on the use of instruments among monkeys? Their publication was spread over eight years during which the two authors progressively developed a conceptualization of the notion of the instrument and corresponding research problematics that were linked with problematics of similar human behavior on several occasions.

The successive titles indicate this evolution: “The Detour Problem” Guillaume, Meyerson, (1930) “The Intermediary Linked to the Object” Guillaume, Meyerson, (1931) “The Intermediary Independent of the Object” Guillaume, Meyerson, (1934) “Choices, Corrections and Inventions”, Guillaume, Meyerson, (1937).

In the first studies, the instrument is present in an experimental frame aiming to explore detour behavior. The authors try to distinguish, within the difficulties the monkeys encounter, those which are due to the instrument, those due to the detour technique and finally, the interaction between these factors. These problems were then compared to the difficulties encountered by the war wounded suffering from certain types of apraxia. In these initial situations, the detour question is given more importance than explorations of the activity with instrument.

However, the specifically instrumental approach then develops throughout the studies and texts that describe them. The mediating, intermediary status of the instrument is affirmed: it is when the experimental situation obliges the animal to understand the properties, either of the intermediary, or of the link between the intermediary and the field, that the problems really appear. The signification of the instrument varies from one animal to another, or even in the same animal depending on its experience and perhaps the conditions of the situation. The instrument is thus an intermediary whose properties must be seen independently from those of its members and associated with those of its members.

This approach is widespread. Our authors write that an instrument is for humans, and it would seem for animals, a sort of intermediary world whose properties are, or can be, different both from those of the body and those of the objects on which the action is exercised. To act efficiently, we need to be able to associate these diverse properties in more or less variable situations. The instrument's use among monkeys and among humans supposes explicit knowledge. This knowledge consists of artificial behavior, true techniques in the sense that there is an acquired art, which includes delicate and precise adaptations of the hand to the tool, the tool to the object and the hand to the object via the tool.

Motricity problems depend on the nature and form of instruments, which are intermediaries that allow indirect action on things. With the instrument and via the instrument, thousands of different situations are encountered and the instrument must be adapted to them. An instrument is a transformer. Learning to handle it means being able to subordinate the motor impulse to its new effects. The reaction of effects on causes is constantly being corrected. At the same time, the instrument is invention in as far as it moves beyond and renews. It liberates pre-trained reactions and constructs and creates new responses, both instrumental techniques and body techniques.

Guillaume and Meyerson, through the idea of body techniques, thus linked their explorations to studies that Mauss (1935) developed elsewhere in anthropology. However, human intelligence is not reduced to that of anthropoids. In a text from 1980, for example, Meyerson is very critical of studies done on the language of monkeys (Gardner 1972, Premack 1976). Through language learning, children enter the world of expressions and possibilities that make up the world that is specifically human. Meyerson affirms that this cannot be confused with the experimental mumbling of the few monkeys analyzed by the authors who were looking for hidden treasures that did not exist.

Is practical intelligence an inferior form of intelligence?

Based on studies of children, particularly on practical intelligence, Rey (1935) also questioned relations between the instrument use behaviors of children and monkeys. His starting point was research by Koehler (1927), as well as the possible extension of some of his observations to adult behavior.

For example, he observed that a child who has begun using instruments has great difficulty in seeing the tool independently of the activity he/she imparts or wishes to impart to it. The action's orientation causes the objects to disappear by absorbing them into a dynamic structure in which environment and self are not differentiated. Rey looks at possible similarities with adult behavior in certain activities that engage sensory-motricity: during delicate manual work (taking apart a mechanism or drawing, for example), do we clearly distinguish the instruments used?

However, Rey's work is interesting for another reason. His analysis of the origins of research on practical intelligence reveals, although he does not stress this himself, that from the outset, the activities with instrument approach was disconnected from an instrumental conception taking into

consideration symbolic systems. The reference was the very young child, the animal or the abnormal child. This option led to the view that practical intelligence was an “inferior form of intelligence”. The possibility of a generalized approach to instrumented activities, taking into consideration instruments that activated the highest levels of cognitive activity was closed from the very start. This no doubt also explains, at least partially, the lack of studies based on problematics of practical intelligence.

We believe that what we need today is the development of a generalized conception of the instrument that allows us to apprehend its status and the activities it is associated with on every level of cognitive functioning, including the highest levels. Of course, this concerns symbolic instruments. Yet beyond this, it is the instrument’s status in work and everyday life activities linked with contemporary technology that makes this update necessary.

However, the study field of training and the evolution and transformation of sensory-motor activities constitutes, as we have seen, a domain in which the question of activities with instruments is highly relevant, even if it is in different terms for people and animals.

In reading Bullinger (1987a & b) who looks at these issues in children, one can only be struck by similarities between his analyses and studies by Guillaume and Meyerson. However, the former extends the reflections of these authors whose series of articles ended with an affirmation that perhaps temporarily blocked potential instrumental research: “It is the instrument that leads to invention. We invent little when we are only faced with our own bodies.”

In suggesting that the body is the subject’s first instrument, Bullinger breaks with this affirmation and opens up the possibility of not only a questioning of the process of instrumenting the body, but also the possibility of placing these questions in a more general problematic of the psychological status of the instrument and activities with instruments.

His approach is grounded in a double reference to Piaget and Wallon.

Along with Piaget, he argues that the subject’s activity should not be confused with the functioning of the biological machine. This would add up to evading, as far as the psychological subject is concerned, the issue of the origin of instrumental activities: the body is, and perhaps above all becomes an instrument for the subject. But for Bullinger, the problem of instrumentation must also be examined in a light that reveals the fact that instrumental elaborations go well beyond biological organization.

He joins Wallon in considering that environments are a means of activities for the child. The organism, which is the main object of instrumentation in young children, is not the only instrumentable element: those exterior to the biological organization can rise to the status of means⁵.

⁵ Let us remember that Bullinger placed himself in a sensory-motricity instrumentation perspective.

Thus, stresses Bullinger, problems of motor control may not stop with the naked hand but extend to the hammer being held.

In this, he extends studies by Guillaume and Meyerson, questions put forward by Rey, as well as hypotheses by Vygotsky (1930) who considers that children, in their development phase, are instrumented with a wide range of instruments. The levels of development are differentiated by the level and nature of the equipment and thus, by the degree of control over their own behavior.

From the epistemic subject to the psychological subject: genetic psychology's move toward acknowledging techniques

In a profoundly different perspective, another researcher from Geneva, Mounoud (1970), developed research on the child's structuring of the instrument.

He confronts children with tests of problem solving by the construction and use of instruments (inspired by those of the preceding authors) that seem to him the most suitable to studying the formation of true and false logic norms. Tests with instruments have the advantage of containing material criteria of success and failure, which the author sees as the only ones possible for the very young children (aged 2 to 7) that interest him. They were also chosen because they allow him to closely study the processes of action interiorization and reflective abstraction that are his main points of interest.

Mounoud's approach is thus situated in a perspective of genetic psychology that consists in seeing action and thought as modes of exchange and adaptation between the subject and the outside world. It aims at defining, thanks to behavioral evolution in the chosen tests, the interiorization of action schemes from the point of view of their general coordination as well as that of the appropriation of the physical environment.

His perspective is thus only vaguely linked to questions of a psychological approach to techniques and artifacts. Nonetheless, the author describes his tests as indicators of practical problem resolution and from the outset, takes into consideration the specific nature of the instrument, i.e. upholding a simultaneous complementarity in terms of the subject's actions and the objects he/she applies them to.

Perhaps this is one of the reasons that his studies, although very interesting, have so far sparked little follow-on research, including in the author's own work.

His research is situated in a theoretical frame of Piagetian thought. As Vérillon (1988a) points out, this does not attribute a specific place to artifacts or fabricated material objects. The object submitted to the Piagetian subject is an ahistorical object: its essential property is that it is determined by physical laws. That these laws were constructed in the object by nature or artificially is not, in this perspective, a pertinent difference. The introduction of artifacts in Piagetian experiments is essentially linked to their ability to facilitate

identification of invariant properties of the real or their importance in terms of analyzing behavior in a structural perspective.

Inhelder and de Caprona (1992a) remind us that the profound originality of Piaget's work was in orienting his work toward the study of fundamental knowledge categories, without which no adaptation to reality would be possible. This option allowed the creation of a fundamental psychology dealing with the construction of notions such as space, time, causality, etc. Piaget's problematic is entirely turned toward the cognitive genesis of properties of the real and actions that progressively constitute structures, categories and knowledge instruments. Mounoud's research was essentially grounded in this frame.

However, the psychological approach to activities with instruments in our opinion comes mainly under another perspective oriented toward the functional analysis of the psychological subject's behavior. This perspective is centered on the dynamics of subjects' finalized behavior and organized actions, their goals, choice of means, controls and the specific heuristics allowing them to attain a particular result via several different paths.

In this decidedly functionalist perspective, a series of important studies around those of Inhelder and Cell  rier and complementing those of Piaget (to which they made a major contribution) have developed since the late 1970s concerning cognitive micro-geneses in finalized behavior.

Yet in Geneva, the idea goes back even further. As of 1954, at the Fifteenth International Congress in Psychology, Inhelder (1955) put it forward and generated interest among psychologists who were then engaged in the beginnings of what is now known as the "cognitive revolution", particularly Bruner's.

From information processing to situated cognition. Which status for techniques?

Bruner (1991) reminds us that psychology today is affected by two revolutions: the cognitive revolution since the mid 1950s and only now, contextualism which is fundamental. Knowledge and cognition are considered by these as contextualized and distributed, transgressing the individual's limits. The author aims to reorient the cognitive revolution (of which he was one of the instigators) toward its founding principle: "the construction of signification"⁶.

For Bruner, the idea that signification is unrelated to information in the computer sense, definitively disqualifies theories that consider people as elements in the transfer of information in a flux. He says that we must break

⁶ Pr  vost (1994), who considered Bruner's book as a milestone, highlights its unusual editorial past: its author is J. Bruner, leader of American cognitive psychology, at least that of the East Coast and more specifically, New York. He teaches at Harvard University and initially wrote this book as an internal report for this university. A French editor had it translated and published it in 1991. According to Pr  vost, it was not until autumn 1992 that Harvard distributed it in a less confidential manner.

with paradigms that require making what we study artificial to the point where it becomes difficult to recognize a representation of a human life.

He puts forward an analysis of the evolution of ideas within the “cognitivist revolution”: little by little, the focus shifted from signification to information and from the construction of signification to information processing, under the influence of the now dominant metaphor of the computer. It is in this light that we ended up evaluating the validity of a theoretical model, despite the fact that information is indifferent to signification. In computer terms, information contains a message pre-coded in the system: meaning precedes the message. It is not produced by the computer and is not at all in its domain.

The concept of computability replaced that of signification, and the cognitive processes of programs used on the computer were identified. Complex programs were apprehended as virtual minds and real minds as comparable to the former. Partisans of the Stimulus-Response model adhered to this in replacing stimulus by entry and exit by response... The new paradigm left no room for the mind understood as an intentionality of states (believing, desiring, pursuing an objective, understanding a signification): the new anti-mentalist science was to banish intentionality. A simultaneous attack was launched on the concept of the agent, which implies that the action is conducted in the realm of intentionality.

For Bruner, the central issue in psychology is thus a creation of a science of signification and processes by which it is created and negotiated. Signification and interpretation are the founding principles of a psychology that is not interested in behavior, but rather in action, its counterpart grounded in intentionality, or more specifically, in the action situated in a cultural whole and in the reciprocal interactions of participants’ intentions. Human, material or intellectual tools participate in culture. People find in them the means they need to go beyond and sometimes redefine their natural limits.

Language learning, a symbolic tool, is instrumental. The analysis of accounts allows us to identify “naturally” significant categories of action for people: in their makeup, they respect the elements identified by Burke: an agent’s action, in order to reach a goal, through instrument use, in a scene that imposes certain constraints.

The identification of material or symbolic instruments as participants in culture is in line with approaches developed by several of the preceding authors. Bruner places instruments in contemporary debates on the evolution of psychology. His choices lead him to place concepts of signification and people as agents (subjects) of a situated and contextualized action at the heart of psychology.

These choices are also those underlying our approach to activities with instruments and we will see that they are far from arbitrary. Their necessity also comes from the issues and difficulties faced by psychology when it intends to contribute to the design of machines (even the most contemporary) when these machines constitute a means of working for operators.

The evolution of ideas in work psychology and ergonomics

These issues go back a long way in work psychology and ergonomics. In the mid 1960s, research on intellectual activities in work on instruments was undertaken in several sectors, as Leplat and Pailhous (1973) remind us: air navigation control (Leplat and Bisseret 1965), the chemical industry (Savoyant 1971), rolling mills (Cuny and Deransart 1971) etc.

The basic situation common to these different studies is one in which the operator's action is mediated by an instrument-tool, machine or remote control device. This instrument transforms the action as well as the information provided to the subject for this action.

In these studies, the stress is placed on the operator's representation of the device or artifact's properties. Leplat and Pailhous highlight the necessity of carefully distinguishing between dimensions relative to the machine's operation (for the expert, the operator, etc.) and those relative to its use, keeping in mind its goals: "in requiring that operating rules be defined before studying utilization rules, we risk embarking this research on a slippery path... we risk ending up with rules that are logically coherent but have nothing to do with the subject's activity".

The distinction between the utilization plan and the operating plan effectively corresponds to modalities of approaches to instruments that users can differentiate, as Richard (1983) indicates in his research on functioning rationales (centered on the process used in the machine) and use (centered on the user's action and activity).

In the mid 1960s, the "Soviet" school of psychology developed similar questions. (studies by Ochanine 1966, 1978 are significant examples) warning against the naive realism of engineers and proclaiming the necessity of developing an anthropocentric point of view (although this term was not used at the time). According to this view, it is the model that the operator constructs of the machine in line with the finalization of his/her activity that should be the focus of interest.

The subject, his/her finalization, the significance he/she attributes to action situations that Bruner considers as needing to be at the heart of contemporary psychological research, have thus been major issues for studies in work psychology and ergonomics for a long time. Evolutions in technology and production systems have only served to reinforce these explorations, while orienting them toward an acknowledgement of the specific forms of complexity and new instrumental potential generated by these evolutions.

Leplat (1991) stresses that the complexity of work, further increased by the development of new technology, leads to many accidents that reveal the extent of the dysfunction of the complex systems users are associated with. The problem of designing truly efficient work aid systems thus becomes crucial.

Leplat distinguishes two diametrically opposite trends for the design of such aids given the different options in operator-robot task distribution:

- One of the solutions is the tool-prosthesis, in which the tool replaces the operator for a certain number of tasks (but then we tend to move out of the instrumental situation frame) and the operator deals with problems the robot cannot deal with;

- the other solution involves collaboration between an operator who is indeed competent but has access to limited resources, and what Leplat calls a tool-instrument.

He thus generalizes analyses by Roth, Bennet & Woods (1987) who develop this same distinction between prostheses and instruments concerning cognitive tools born of artificial intelligence:

- prosthesis type systems are defined as a means of compensating for human deficiencies. In this paradigm, the focus is more on the system's construction than its use and the operator is essentially in the position of interface between the machine and his/her environment. Control is carried out by the machine part of the operator-machine system. The operator is in charge of providing data to the expert system as well as taking into account and applying the solutions proposed;

- systems defined as instruments are defined as means allowing competent users to perform tasks. In this paradigm, subjects' competence in the construction and use of tools is considered as a resource allowing goals to be attained. Unlike the prosthesis perspective, the user has an active role. The instrumental point of view on cognitive tools leads to using computer technology not as a means of production or of recommended solutions, but to help the user reach his/her own decisions.

As several authors have indicated (Woods 1986, Woods, Roth, & Bennet 1990, Bainbridge 1991), the relation between the machine, the computer and the operator is moving toward cooperation and collaboration.

Nonetheless, the design of such cooperative aid instruments is extremely demanding, both in terms of the analysis of systems and that of the activity of the operators concerned. The extent and difficulty of these demands seem to have been long underestimated, even if current interrogations, particularly in the study field of human-computer interactions indicate a renewal and reorientation of the issues.

The idea of aid systems that assist diagnostic activity and the elaboration of solutions tends to be developing in this direction (Falzon 1989). Such systems no longer aim to provide operators with an answer (or the best possible answer by a sort of analogy with Taylor's "one best way"). Rather, they seek to help the operator in his/her own analysis activity. The operator associates the system with his/her activity in a collaborative relation. This type of design choice is clearly anthropocentric: operators and their activity are placed at the heart of the device, which is designed from the outset to be

associated with them. It is in line with the instrumental paradigm described by Roth, Bennet & Woods (1987).

The necessity of reconstructing psychology to allow a real contribution to the design of technical systems

It was also in a perspective of critical reflection on psychology's contribution to design in human-computer interactions that in June 1989, a number of research leaders in this field participated in an important seminar in a New York hotel. Participants agreed that a wide gulf separated psychology and the HCI field⁷. The conclusion, put forward in the Kittle House Manifesto, is that psychology needs to be reconstructed (Caroll 1991b): in the 1970s, psychologists applied laboratory methods with modest success; in the 1980s, they applied information-processing theories with poor results.

Criticisms concern both HCI psychology's ability to pertinently describe users' and designers' activity and the inadequacy of the proposals it put to designers.

The "Human Factors" paradigm is criticized because of the place it accords psychology, i.e. essentially the *a-posteriori* evaluation of a system already designed. This evaluation is considered to be of little use to design because it produces few improvement proposals and those it does produce, often appear too late.

Methods based on the frequency of errors and performance times are considered to contribute few elements capable of enriching design: many theories can only be used to model very narrow phenomena.

The computer metaphor is strongly debated: users do not recognize their own work in task descriptions in terms of information processing. These analyses are often considered too weak to aid design.

In a text from the same publication, Bannon and Bodker (1991) develop the question of signification. The positions of classic cognitivism and its experimental approach are criticized on these grounds: analyses concern individuals without reference to their culture and their history; problems are defined and evaluated by the experimenter and placed in an unfamiliar environment; the real nature of the task and expected behavior are often not apparent to the subjects and the question of signification for the subject is only rarely explored; performance is evaluated in terms of rationality norms that are external to the subject and his/her deviation from these norms.

Bannon and Bodker also consider that HCI research currently neglects essential facts: developmental aspects relative to both tools and user competence. The analysis of skills acquisition comes under fire because it only looks at the first hours of use. A long-term approach to skills and competence development is recommended.

⁷ HCI is an abbreviation of "Human Computer Interaction".

Finally, according to the manifesto, design aids grounded in the psychology of information processing (guidelines, rules, etc.), seriously underestimate the complexity of the design process. Under Simon's influence, they treated this complexity as if it could be partially broken down hierarchically which led to a distorted view of the process. The models and guides based on an apprehension of design in terms of problem solving are not considered very pertinent in that they are not coherent with real design mechanisms (the possible solutions are not likely to be identifiable; the breaking down into sub-problems does not advance the solution to the global problem; partial and temporary solutions do not participate in the final solution but play an important role in the space specifications of the final design; the design process includes the discovery of new goals). Psychology thus needs to aspire to understanding the processes of real design.

Generally speaking, according to the manifesto, HCI psychology needs to be enriched methodologically and conceptually. It should be both more diverse and more specialized.

The development of action and activity theories, the description of tasks and the view of artifacts as psychological objects are seen as a group of unprecedented intellectual tools in this perspective. Several of the book's authors recommend the incorporation of the methods and concepts of developmental approaches in HCI psychology.

The relation to artifacts and techniques: a central issue for psychology

This renewed psychology called for by the Kittle House manifesto and to whose emergence it contributes, must treat relations to artifacts as a central concern. These relations need to be explored along two lines corresponding to two forms of human activity:

- design activities: it is necessary to have a better understanding of the mechanisms and processes by which artifacts are designed to provide designers with real aids. Assisting the design activity supposes that the aids proposed be coherent with this activity. They must integrate it, rather than hinder or even prevent it;

- usage and utilization activities: it is necessary to analyze and understand what these activities are from the perspective of the users themselves, as well as their modalities and significations that occur within social situations and contexts whose singularity and complexity must be respected.

According to the authors, understanding through psychology the processes at work in the fields of use (specificity principle) and design (applicability principle) is crucial to the creation of the contextualized science necessary for design. Respecting the singularity, the complexity and the signification of the context is thus considered as a condition for applying psychology and more generally, all forms of science.

The signification of the result of instrument use as well as the instruments themselves, in reference to action and activity is also an essential dimension for Bannon & Bodker (1991). In the same publication, after a discussion of traditional HCI models, they present an alternative theoretical frame for real activity and use of artifacts in work situations⁸. They suggest not considering computers as objects, but rather as tools and instruments. They define guidelines to such an approach:

- artifacts exist in activity and are constantly transformed by activity;
- artifacts must not be analyzed as things but rather in the way they mediate use; studying mediation is thus essential for HCI;
- artifacts are not only individual means; they are bearers of the sharing and division of labor;
- their signification is incorporated in a social practice.

The link between artifact design, tasks and work is also at the heart of interrogations by Greif (1991) who considers that machine design should be part of the design of work as a whole. Work activities are constituted through the design of real tasks and tools.

An instrumental approach is also put forward by Payne (1991) who refers to Vygotsky and Bruner: for him, the fundamental point is that thought is formatted by tools. He advises analyzing the way in which artifacts structure the task, both in bringing up new questions (artifact-centered problems) and in contributing new resources for performing the task and moving beyond these new problems.

In the same way, Kuutti (1992) develops an instrumental point of view based on activity theory, which for the author, brings HCI a new vision compared with the standard cognitive science point of view (communication between two information processors): there is no longer question of a user interacting with a computer, but an active subject using an application program as an instrument to manipulate objects in such a way that the result of the manipulation is, for the user, significant in the context of the activity.

Many of Norman's studies look at the psychology of everyday activities (1988) as well as the consequences to be drawn in a design perspective

⁸ The question of signification is placed at the heart of the issue of the necessary renewal of a psychology that aims to describe human interactions with artifacts and more generally, the appropriation of techniques. We could say that studies in the field of cultural psychology naturally lean this way. Bruner is not alone in this. Cole (1989) puts forward an overview of the birth, death and current revival of interest in the culture of artifacts and states that cultural psychology is grounded in two major theses: human skills in the creation of artifacts; and the skills corresponding to the transmission of knowledge thus accumulated to following generations. In our opinion, these theses converge with old explorations on the differentiation between humans and animals (with all the studies carried out from this perspective in using the tool as a differentiation criteria) and those of cultural theories of human nature and the external transmission of the cultural capital of the species (an important theme in Soviet psychology).

(Norman and Draper 1986) He also looks at approaches to activity from of the Soviet school (Vygotsky 1978, Luria 1979, Leontiev 1981) and their followers (Wertsch 1985b).

In a text from 1991, he highlights the role of Soviet psychology in the field, the way it was forgotten and even repressed under behaviorism as well as the current revival of the problematics it has inspired.

Norman distinguishes two points of view: “the system view” and “the personal view”:

- the system view is that of the external observer who looks at how the human-artifact whole accomplishes a task. This is the classic human-machine system view in which the system is considered in terms of a centering on the process;

- the personal view is based on the analysis of the modifications brought about by the use of an artifact: what is transformed in the task, what must be learned, the procedures that must be abandoned. This view aims to analyze both the aspects linked to the task and those linked to the activity

Norman looks at the effects of artifacts on activity. He distinguishes several dimensions of influence in terms of the distribution of actions in time (precomputation), the distribution of actions among people (distributed cognition) and the changes in actions required by individuals in order to perform the activity. He considers that the construction of artifact typologies is an important task for psychology and suggests distinguishing between passive artifacts such as books and active artifacts such as computers.

The instrumental approach is situated in a “personal view” and like Norman, we think it is necessary to analyze the object’s influence on the recomposition of tasks, the appearance of new tasks and the disappearance of old tasks. He analyzes, for example, the problem of checklists to demonstrate that their use is itself a task that introduces new tasks: making up the list, remembering to consult it, reading and interpreting the items on the list.

Yet we feel it is necessary to go beyond an approach in terms of tasks, toward analyses based on the hypothesis of a total recomposition of the activity in line with the perspective opened up by Vygotsky with the concept of the instrumental act. The results that we have obtained in the robotic field (Rabardel 1990, Rabardel 1991a, Rabardel 1993b) follow these hypotheses: the very conception of the world in which the user acts via the instrument is transformed. In the same way, in computer assisted design (Rabardel & Beguin 1993, Beguin 1994) we highlight the emergence of a specific way of handling the activity’s objects as operating materials in line with an anticipation of future productions and the instruments that will be available at that time.

We have seen that the idea of the necessity of a specific psychological questioning of the modalities and characteristics of human relations to artifacts is widely held, in both fields of everyday life and in work with

instruments such as computers. The necessity of psychological questioning is also emerging for activities in relation with complex technical systems.

Norros (1991), for example, lays out the characteristics of FMS (flexible manufacturing system) technologies:

- These technologies are systemic and evolutionary; their application is progressive and complex. The design process continues during use of the system, both in operators' working methods as well as technical solutions and organizational structures. Thus, says Norros, a participatory design process is necessary;

- new activities are required by the tool's new characteristics, in particular mediation to bring about both a sensorial distancing from the operator and visibility given to the characteristics, properties and system states that are of course invisible;

- the respective roles of explicit and tacit knowledge are altered due to the uncertain nature of situations that require diagnosis and decision for action.

We are at the limits of the instrumental approach, at least in the terms we wish to give it in this publication. The question of the nature of instruments and the associated forms of activity in process surveillance and the control of the dynamic environment are of course important. However, our own studies in this field are too limited today for us to take the risk of generalizing.

Future directions for the definition and analysis of activities with instruments

At the end of our exploration of the literature, it appears that even in the field of sensory-motricity where activities with instruments have been studied most, a lot of empirical and theoretical work remains to be done. Beyond this, we feel the superior forms of activities with instruments must be studied in terms of their relations with sensory-motricity and the originality of their own forms.

We are looking not only at psychological instruments⁹, but also at instruments born of contemporary technology and production modes that allow and condition action and activities oriented toward the world of objects.

A project such as this is naturally grounded in the fields of human activity that are directly concerned by activities with instruments: first of all in work, a prime source of complex and standardized uses; education and training where instrumental competence develops and fundamental psychological instruments are constructed; and lastly in daily life, where uses multiply and are reproduced day after day and are also diversified following sometimes random encounters.

⁹ As Vygotsky understood it: they allow one to act on oneself or on others. We will return to this notion in the following chapter.

This direction in psychological research could only truly develop if it respects the complexity, variability, diversity and singularity of real situations in social life. In various forms, this is what the majority of the authors we have referred to have called for. It is the true meaning of a contextualist renewal that is now vital for psychology.

Work, training and daily life cannot be considered as areas in which a universalizing and asocial form of psychology can be applied that would inject into it data supposedly fundamental for its application. The limitations of this perspective have led, for example, to today's calls for an overhaul of HCI psychology. Work, daily life and training are areas in which psychology aiming to take psychic activities into consideration in terms of their human specificity and diversity should be developed. In taking these elements into consideration, it will then produce results that can effectively be reinvested for the transformation of situations within which people live their lives.

PART TWO: THE NOTION OF THE INSTRUMENT

The aim of this second part is to develop an overall theoretical frame for the analysis and conceptualization of activities with instruments. The elaboration of such a frame requires a psychological definition of the notion of the instrument. This will be the objective of chapter 3. It will lead us to conceive of the instrument as a mixed entity made up of an artifact and a scheme.

In chapter 4, we will examine instrumental geneses, i.e. the subject's elaboration of his/her instruments. Finally, in chapter 5, we will analyze the effects of instrument use on the subject's activity and put forward a group of concepts allowing us to define and account for these effects: required activity, expansion of the range of possibilities, operative transparency.

CHAPTER 3: INTRODUCTION TO THE NOTION OF THE INSTRUMENT

In the beginning of this chapter, based on an examination of different approaches, we will suggest considering these objects and technical systems as artifacts. We will then describe the instrumental relation to the artifact as one of the possible relations to artifacts. In the third part, we will describe activity with instrument situations and put forward a triadic model of this class of situation. We will then examine the different views of the instrument in psychological literature, before presenting a summary.

Technical object, fabricated material object, artifact

In the famous article "Technology as a Human Science", Haudricourt (1964) stressed the possibility of a variety of views of the technical object: "Take this table. It can be studied from a mathematical point of view - it has a surface and a volume; from a physical point of view - we can study its weight, its density, its resistance to pressure; for from a human science point of view - the origin and function of tables for mankind".

This range of possible perspectives corresponds to different analysis issues as Bibard (1991) explains. Technical objects can be described as belonging to the technical systems they fit into (this is the innovation sociology approach). They can also be seen as part of technical branches (B. Gilles' approach), or as forming part of socio-technical systems that are restricting for people (an essentially economic point of view). Bibard embarks on an analysis aiming to explain what is contained in things, what is inscribed in them to make them usable and useful, and what defines their coherence and relations with their surroundings.

This project is not unrelated to the views of Simondon, one of the contemporary philosophers who has explored technique most thoroughly. In 1968, having observed that culture has set itself up as a defense system against techniques, he aimed to demonstrate that in ignoring technical reality, it ignored a human reality.

He defined the technical object as an intermediate type of reality, a reversible mediation between people and the world, and a paradigm of the relation between the living and the environment. For Simondon, the meaning of the technical object is how it works. Studying invention introduces an understanding of the object's internal essence as a reality with its own coherence. Biological study, on the other hand, makes it appear as a functional bridge between heterogeneous realities: organism and environment. Comparative technology, studying technical objects, must thus focus simultaneously on their functional dimension (ordering different means according to their usefulness) and their internal perfection as technical beings.

For Simondon, technical activities, at the most elementary level, appear essentially as functionally useful mediation. However, at a higher level, criteria of inherent perfection take over. The evolution of technical objects means progressively eliminating operators as a source of energy (machine tool), then of information (complete machine), to the networks by which the world which becomes a technicized environment with which the operator has contact via interfaces.

This approach is behind several studies, particularly in the tradition of technical genetics (Deforge 1981). Yet it reflects an inherently technocentric point of view in that it values the internal perfection of the technical object, thus undermining the status of the being, of the technical individual. This intrinsic point of view sees the technical object as a being that is moving toward autonomy, i.e. the elimination of the operator.

For the author, object usage activities have a "minority status", while the engineer or designer's relation to the object has a "majority status". These terms do not have negative connotations for Simondon: he feels a halfway path between minority and majority statuses is an appropriate relation to technique. However, they will inevitably lead him, perhaps despite himself, to effectively only according a minority status to usage activities, i.e. to people's activities when they uphold an instrumental relation to the object.

As Bernoux (1991) indicates, stressing the minority-majority opposition leads to the idea that the user's practice contributes nothing to knowledge of the technical object. We feel that it even leads to a denial of the usage activity, particularly in the workplace. Thus, for Simondon, the technical object has been apprehended through work as an instrument, supplement or product. He feels there should be a turn-around to allow that which is human in the technical object to appear without being seen in terms of the work relation.

The consequences of this view will have even greater importance among those who, based on Simondon's research, will have a completely unilateral interpretation of the technical object, whose uses will be only be seen in light of designers' anticipations. Many other researchers besides Simondon have, like him, contributed, despite themselves, to the notion that the technical object is predominantly associated with a technocentric point of view.

It is a problematic situation that makes the examination of the technical object difficult from other points of view than that of the technique itself. For this reason, we have replaced the term technical object with that of "Fabricated

Material Object” (FMO). The term “technical object” thus designates a fabricated material object seen from a technical point of view, just as the term “product” describes this same object as something to be designed, made or sold; that of the “instrument”, the object being used, etc. The different terms thus indicate the types of particular relations specific to the fabricated material object (Rabardel 1984, Léonard & Rabardel 1984, Rabardel & Vérillon 1985).

The term “fabricated material object” was chosen to allow the most neutral possible name and avoid anticipating the analysis perspective to be adopted. This undertaking seems even more essential today given the issues at stake in technocentric and anthropocentric design. But we feel the term fabricated material object, a heavy circumlocution, should now be replaced by that of artifact. This word is almost synonymous and its usage is fairly widespread, particularly in the field of human sciences (see, for instance, several chapters in the joint publication Perrin 1991a).

In anthropology, the notion of artifact designates anything that has undergone a transformation, however minimal, of human origin. It is thus compatible with an anthropocentric point of view. Another advantage is that it does not restrict meaning to material things (from the physical world). It can also be applied to symbolic systems, which instruments are at times.

Thus, from now on we will use the term artifact, a “neutral” term that does not specify a particular type of relation to the object. However, we will give a more precise definition than “something that has undergone a transformation of human origin”. We are interested in the thing liable to be used and elaborated so as to participate in finalized activities.

Finalization is constitutive of the artifact’s design, or at least the class of artifacts our research refers to. Indeed, as we wrote about fabricated material objects (Rabardel, Vérillon 1985), its finalization is at the origin of its existence. Each artifact was designed to produce a class of effects and its implementation in conditions anticipated by designers allows production in situation of these effects¹⁰. In other words, each artifact gives rise to possible transformations of the object of the activity, which were anticipated, deliberately sought and are liable to become concrete in usage. Hence, the artifact (whether material or not) makes concrete a solution to a problem or a class of problems raised socially.

Mostly, artifacts have a social status from the outset that goes beyond the one the subject grants it in associating it with his/her action. At the same time, it often remains short of the properties the subject attributes to it or really exploits. The finalization of the artifact gives it particular characteristics, which anticipate use of both real objects on which it can act with the aid of the artifact, and the activities and modalities of action.

Finally, we will use the term instrument to designate the artifact in situation, inscribed in usage, in an instrumental relation of action to subject as

¹⁰ The effect sought can be forbidding a certain type of action or transformation. This is true, for example, of security devices.

a means of the action. This is merely an initial definition indicating a minimal approach to the psychological notion of the instrument and corresponding to one of the weakest uses we will make of the notion of instrument.

Machines and instruments: a question of viewpoints

Artifacts in use within a production and activity system, often called machines¹¹, can be apprehended from several viewpoints, each of which is pertinent in its own way.

The artifact as a technical system

One approach sees the artifact as a technical system with specific features, which is considered independently of humans. This, for example, is the approach that Lafitte (1932) proposes for machines. They are seen as bodies organized by humans that form, within nature as a whole, a sort of reign that in its richness, its variety, the singularity of its prodigious development as well as by the vagueness of its contours, is the same as other reigns we have imagined up to now. This perspective, which was also partly shared by Simondon, is not really a psychological approach to relations with artifacts. It is the equivalent of the way an entomologist sees the ant: the artifact is a thing to know, an object of knowledge.

Nonetheless, focussing on the artifact as a functioning system and structure obeying specific rules and constraints also concerns the operator in action in his/her relation to machines.

This is true of designers whose objective is to end up with an effectively functioning and operational artifact that performs the required functions. According to the colorful image put forward by Coutouzis and Latour (1986), the machine is a machination, a strategy, a trick, in which the forces enrolled control each other in such a way that none of them can extract itself from the whole. The engineer's skill consists in finding a range of ways to implicate each element in the functioning of the others. In this perspective, the system's functioning is seen in light of its design.

This is also true of humans engaged in action: the artifacts in use, even if they did not create them themselves, can be systems for them that function according to their own laws and constraints. They must consider this functioning in the way they use them. For example, a driver takes into consideration the constraints linked to the functioning of his/her car by watching the temperature of the motor, tire pressure, etc.

Yet maintaining the machine in a functional condition may be more than a secondary task (however necessary), as for our driver. It may also be the object of the job, as is the case of maintenance technicians, and to a degree, those in charge of the surveillance of automated installations and major procedures. This requires maintaining the system as a whole as functional

¹¹ In this section, we use the term machine as a synonym of artifact (widely used in technological literature) when the authors themselves use it.

within acceptable limits. For the subject, the artifact is an object to be known so it can be managed in order to make its functioning correspond to prescribed or simply expected criteria. This relation, the **functioning rationale**, as Richard (1983) put it, organizes the relation to the artifact.

The artifact in light of its functions

The relation to artifacts in use can also have a second dimension. It can be focused on the evolutions and changes in state of (material or non-material) objects that the system deals with and acts on. The focus is less on the artifact as a functioning system than on the artifact producing transformations of the product treated, matter or information; on the processes of these transformations; on the successive states; the flux, etc.

Thus the artifact is seen in terms of its functions, of what it produces, i.e. in terms of what happens to objects, to the things whose transformation it contributes to as a sub-group of a larger system, such as a production unit or a company. This sub-group can itself be considered as a mixed operator-machine system that produces transformations¹².

In this perspective, the **process of transforming things** organizes the point of view from which the human-machine relation is apprehended.

The artifact as a means of action

Finally, a third type of relation between operators and artifacts in use is the instrumental relation. The artifact is placed in a finalized activity from the viewpoint of the person using it. It thus has the status of a means of action for the subject who accords him/herself this means to operate on an object. This means may also be accorded to the subject, as in the case of the workplace, for example. Here the relation to the artifact is apprehended from the viewpoint of the subject, of his/her activity and action. In this light, it is **activity and utilization rationales** (to use Richard's terms once more) that organize the approach to the instrumental relation of humans to artifacts.

Functioning, use and process as complementary rationales

Naturally, the instrumental relation does not exclude other types of relations to artifacts in use. These are very often complementary to the instrumental relation, or even integrated within it. It is often necessary for the subject to maintain the artifact in a functional state (functioning rationale) and manage the process of transforming objects (process rationale) so that the artifact is an efficient means of his/her action (use rationale, instrumental relation).

Let us take an example in the domain of plastics extrusion. The operator runs a machine that allows the fabrication of a plastic film whose thickness must be constant, give or take a few microns. The operator is responsible for

¹² For example, it is this last option that underlies Coutouzis and Latour's affirmation that the actors of such systems can be freely chosen among humans and non-humans.

the quality of the film. The plastic matter reaches him/her in the form of granules, is melted in an oven and extruded as a film. Having observed an irregularity in thickness, the operator hypothesizes that the filter that homogenizes the matter in fusion is partially clogged (functioning rationale), leading to an insufficient flow of matter causing irregularity in the product (process of transforming things rationale). The operator increases the temperature of the oven (utilization rationale) so as to make the matter more liquid and thus reinstate the quality of the product.

This example illustrates that the operator's instrumental use of the machine (i.e. as a means for his/her action) to attain quality objectives can involve considering the functioning rationale as a transformation of things rationale. It also shows that only part of the machine (the oven temperature setting) constitutes the operator's instrument, rather than the machine as a whole. The instrument is thus not given once and for all and interchangeable with the machine itself. It is the product of the operator's choice, who associates the machine, artifact, or most often a sub-group of the artifact with his/her action.

CHAPTER 4: THE TRIAD NATURE OF ACTIVITY WITH INSTRUMENT SITUATIONS

Despite major differences in the way they conceive of artifacts and instruments, most of the authors mentioned explicitly (or sometimes implicitly) distinguish between three poles engaged in instrument utilization situations:

- **the subject** (user, operator, worker, agent, etc.);
- **the instrument** (tool, machine, system, utensil, product, etc.);
- **the object** towards which the action, aided by the instrument, is directed (matter, reality, object of the activity, of work, other subject, etc.).

We will see that the meaning of each of these poles varies greatly depending on the author and the viewpoint underlying their interpretation system. Nonetheless, the principle of situating the artifact in a position that is both intermediary and mediating between the subject and the object seems to be a widely held option. We have shown elsewhere (Rabardel 1993a) that even when authors do not refer to it explicitly, a careful analysis of studies often allows us to identify the same poles.

For this reason, we have put forward the I.A.S. model to describe classes of Instrument-mediated Activity Situations (Rabardel & V rillon 1985). This triad model (fig. 4) brings out the multiplicity and complexity of relations and interactions between the different poles, unlike the usual bipolar models of subject-object interaction situations. Beyond direct subject-object interactions (dS-O), many other interactions must be considered: interactions between the subject and the instrument (S-I), interactions between the instrument and the object on which it allows one to act (I-O), and finally subject-object interactions mediated by an instrument (S-Om). Furthermore, this whole is thrown into an

environment made up of all the conditions the subject must take into consideration in his/her finalized activity. Each of the poles and each of the interactions that we have just examined are themselves liable to be in interaction with the environment thus defined.

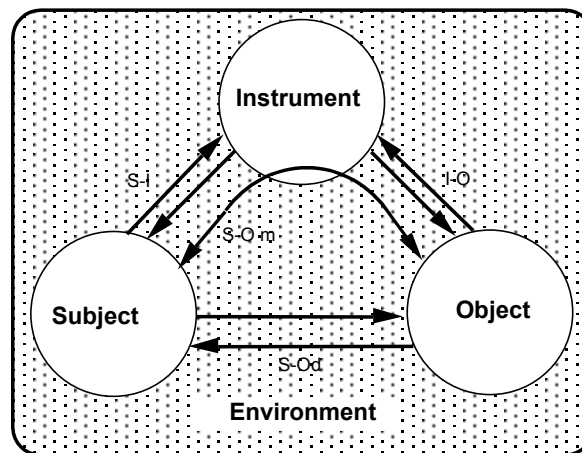


Figure 4

I.A.S. Model: the triad nature of Instrument-mediated Activity Situations (based on Rabardel & V  rillon 1985)

The I.A.S model is a tool for the analysis of tasks and activities. Let us take an example borrowed from Aucherie and Sacotte (1994). It concerns a professional painter preparing the walls and ceiling of a room by using a wallpaper removal machine¹³. A fast observation of the activity allows us to establish an initial description. The painter runs the plate of the wallpaper removal machine over all the areas covered in wallpaper. At the same time, he scrapes with a spatula the wallpaper that comes off due to the steam. He then applies the machine to the ceiling and explains that he has discovered that the heat makes the areas in poor condition more fragile: he then has to merely scrape them lightly with the spatula. This description of the activity is analyzed in terms of the status of the different elements in table 5.

The example of analysis based on the I.A.S. model presented in table 5 immediately reveals certain essential characteristics of activities with instruments. First of all, the objects of the activity are numerous: plaster, wallpaper, ceiling and vary at different times. Likewise, there are several instruments: wallpaper removal machine, spatula, steam. For the subject, a single technical device (the wallpaper removal machine) incorporates several instruments: in the phase examined, these are the plate and steam, but at other moments, for example when starting up the machine, elements such as the cover of the heater, the gas tap, etc. are liable to have the status of

¹³ The device produces high-pressure steam. It consists of a hollow metal plate, which on one side allows the steam to escape through a series of holes (like an iron) and on the other side, has a handle that allows the user to manipulate it.

instruments. Unexpected elements have the status of instruments, such as steam. Finally, the painter uses the wallpaper removal machine to carry out tasks not foreseen by designers: weakening the plaster. We will come back to this point in detail in the chapters devoted to instrumental genesis in which we will analyze the signification of this "misappropriation" as being part of activities of elaborating instruments by users.

ACTIVITY	SPATULA	PLATE wallpaper removal machine	STEAM	PLASTER	WALL PAPER	CEILING
Painter runs wallpaper removal machine over wallpaper		instrument	instrument		object	
Using a spatula, he scrapes at wallpaper which comes off under the effect of steam	instrument		instrument		object	
He runs wallpaper removal machine over ceiling		instrument				object
The steam weakens plaster			instrument	object		
Painter scrapes with spatula	instrument			object		

Table 5

Example of the analysis of activity based on the I.A.S. model.

Of course, it is clear that the I.A.S. model, even in this simple example, does not cover all the characteristics of situations in which activities are mediated by instruments: the range of instruments used by a single subject in a complex action; the very variable and sometimes collective nature of the action's contexts; the subjects' specific finalizations, etc. Yet the instrument is present, and this presence constitutes the resulting triad and multiple interactions that form a common core, characteristic of the class of instrument-mediated activity situations.

However, as we will see, this shared core is liable to be interpreted in several ways.

A techno-centered approach

The COST report in 1991 on the definition, state of the art and scientific perspectives in the field of human-machine communication gives an elaborate expression to this type of approach¹⁴.

The user and the machine are considered as a system thrown into an environment. The aim of this system is to carry out a certain task. The interactive nature of relations between the operator, the machine and the environment is essential. Operator-machine interactions are not simple exchanges of information. Rather, they must ensure the coordination of two intelligent processes that take place, one in the operator's brain, the other in the machine. The machine must thus dispose of a representation of the operator and his/her world, of the object and its world and a strategy allowing it to execute the task in cooperation with the operator and under his/her control.

Focussing on the machine as a machine is manifest: the machine must help the operator to perform a task but he/she must undergo training to benefit from this aid. The machine has to perform two functions: managing the dialogue with the operator and performing the task (or planning).

A tripolar model of human-machine relations is put forward under the name of "operator-machine-object triplet" (fig. 6). We will examine this triadic model in the conceptualization of each of the poles and in that of interactions.

The conceptualization of poles:

- the **human pole** is less constituted in terms of the subject than as a human component (with its own characteristics and properties) of a broader system that goes beyond him/her and in which he/she is inserted;
- the **artifact pole** is considered in machine terms, or of the operating and functional machine. It is thus not at all, or only slightly, an instrumental point of view focused on the system as a means of the subject's action. This view is symmetrical to the view of the operator;
- the **object pole** is considered as that on which the operator-machine system activity is focused. The object pole is made up of the object of the shared activity of the system's components thrown into the environment common to the operator and the machine. Two views of the reality the operator-machine system is faced with are thus distinguished: a view in terms of object (referred to the object of the activity) and another in terms of environment (i.e. the context of the activity).

¹⁴ The COST report is the fruit of a group in which the positions held were far from homogenous. Our interpretation concerns the point of view that we considered dominant in the report.

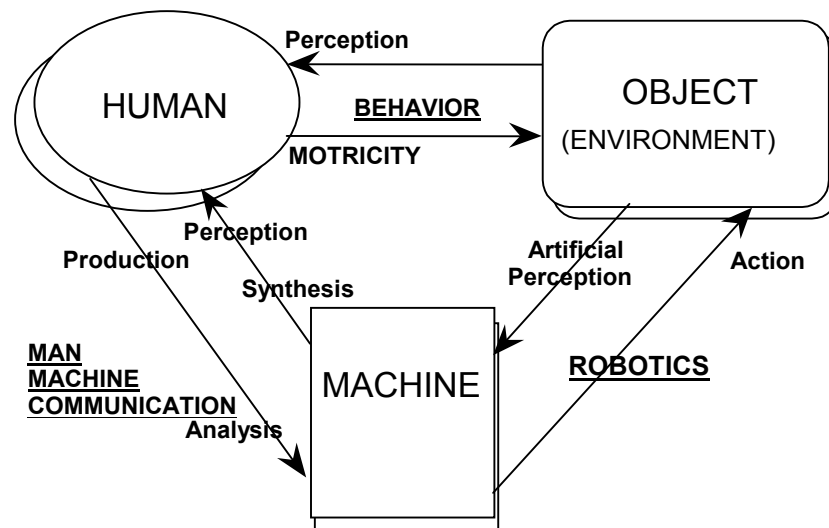


Figure 6

Operator-machine triplet (based on the COST report 1991)

- interactions:

- the different spheres of interactions between both operator and machine and machine and object are present. They allow us to distinguish domains of scientific study: operator-machine interactions being in the domain of operator-machine communication and machine-object interactions in that of robotics.
- however, and this is one of the essential shortcomings, instrument-mediated subject/object interaction is missing. We can hypothesize that this is the result of the view of the operator and the machine, both reduced to the notion of components of a system, i.e. part of a vision in which the focus is on the system itself and in which it is the system that acts.

The predominantly technocentric conception of this triad approach appears in the functions the machine must perform: managing the dialogue with the operator and performing the task (or planning it). In both cases, the operator loses out. This view does not refer to the operator's action and activity but rather to the process of accomplishing a task, which is that of the system as a whole. There is a symmetricizing of the statuses of the operator and the machine. This symmetricizing is perhaps inherent to the notion of the operator-machine system once it is considered in reference to the object transformation process.

Such a conception is of course fully applicable when we have to elaborate technological solutions. Yet it is insufficient when we need to analyze the situation from the viewpoint of the operator engaged in action, i.e. a point of view in which the artifact has the status of a means for this action. This viewpoint is necessary to the constitution of a specifically psychological conceptualization of the notion of the instrument.

The collective's anthropocentric approach

The viewpoint expressed by Norros (1991) which examines the question of developing operators' expertise in FMS (Flexible Manufacturing Systems) grounded in a triadic model (see fig. 7) is systemic. The work process is considered as a socio-technical system of activity and operator activity is examined both as an individual and collective activity.

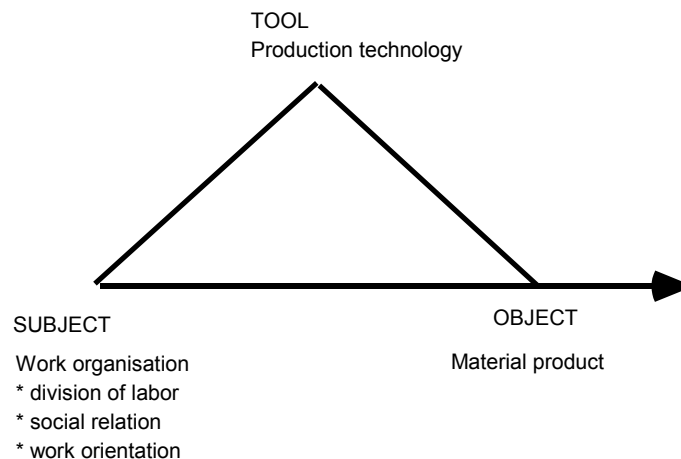


Figure 7 Norros' model (1991)

The view developed by Engeström (1991), inspired by Vygotsky and Leontiev is also systemic, but at an even more general level. He suggests considering the system of socially distributed activity as a pertinent analysis unit. An activity system is constantly racked by tensions and contradictions internal to its elements and among them. In a way, it constitutes a self-organizing machine, virtually producing innovations and disruptions.

The author presents a triad model (fig. 8) of such a system considered as a unified dynamic whole including: the operator and his/her colleagues in the work community (subject); the conceptual and material tools (instruments); the objects of the action (object).

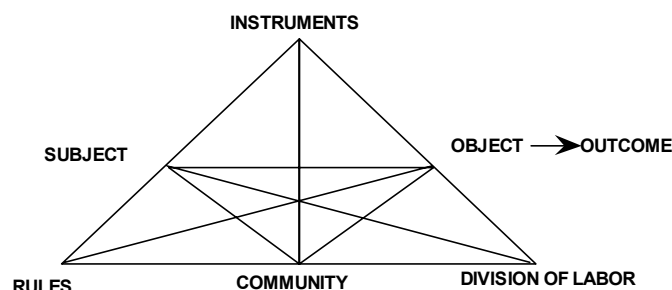


figure 8

Engeström's model (1991)

This model implies several mediations in the activity (between subject and object via instruments, including symbols and representations). Yet the triangle is only the tip of the iceberg. Less visible activity mediators form the basis of the model: rules, community and division of labor. The system is constantly changing and the system's activity reconstructs itself continuously.

The approach as a whole is thus focused on the global system that makes up the company and thus allows the analysis of the collective dimensions of work. The author thus breaks with the idea, described as "Cartesian", of the individual brain as a pertinent analysis unit considering cooperation as a harmonious adjustment of individual work efforts. He defines the Cartesian view of expertise as residing in the individual in the form of tacit or explicit knowledge, skills and mental models.

The subject pole of the triad is defined as a multi-professional team. The move from individual subject to collective subject allows the consideration of specifically collective dimensions of work. Yet this perspective raises problems for a psychological approach to the activity with instrument: is the acting individual, in acting, no more than a fraction of a more global subject? We think that the notion of the collective subject must not eradicate that of the individual subject. On the contrary, it must be coordinated with it. The analysis level of the person remains fundamental in psychology, as in ergonomics and didactics, even if it must not, of course, be the only one considered. We will return to this question in the conclusions of this chapter.

Psychological approaches focused on the subject

Most of the psychological studies we referred to in the preceding chapter are based explicitly or implicitly on a triadic description of activity with instrument situations. Guillaume & Meyerson (1937) thus applied to humans the results of ten years of research done on monkeys: use of instruments among both monkeys and humans supposes real techniques in that there is an acquired art which includes delicate and precise adaptations of the hand to the tool, the tool to the object and the hand to the object via the tool. In this approach, the three poles of the triad are identified (hand, tool, object) and the different interactions highlighted, including the subject-object interaction mediated by the instrument.

For Bullinger (1987a), a distinction must be maintained between organism and subject. The organism is a material object liable to instrumental elaborations. Regardless of the child's developmental level, there is always a "subject" (however young), that organizes and directs instrumental elaborations. Between the subject and the world, there are always sensori-motor systems. Here, the three poles of the triad are the subject, the organism, particularly sensori-motor systems and the world. The operator occupies two of the poles of the triad, one as subject and the other (the instrument pole) as organism.

Of course, this is also true of Mounoud (1970) who describes the instrument as an intermediary world between subject and object (the three poles), by the fact that it associates itself with the subject's actions (subject-object interaction); actions that it transmits to other objects (subject-object

interactions mediated by instrument); because it has complementary relations (instrument-object interaction) with objects (and the context of the task) to which it applies itself.

We could hypothesize that the triadic view can be generalized because the situation corresponding to these examples concerns instruments which engage behavior that is clearly intelligent, but whose sensori-motricity (or "sensori-gestuality" according to Guillaume & Meyerson and Mounoud) occupies a large place. The triadic view of activity with instrument situations is also shared by many psychologists interested in complex cognitive activities.

Thus, in a text from 1991, Norman also analyzes what he calls cognitive artifacts based on a triadic model of activity with artifact situations (fig. 9) whose three poles are the subject, the artifact and the task.

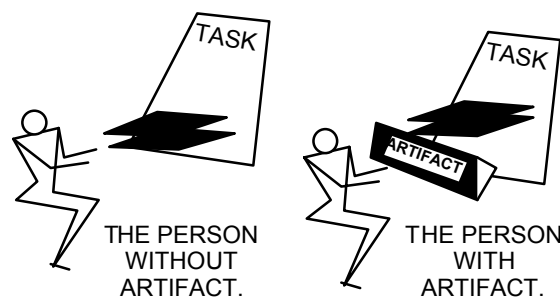


Figure 9: Norman's triadic representation (1991)

Norman distinguishes two types of possible views of these situations:

- a "system" view, which considers the subject-artifact whole as a system and examines what this system can do in light of the task which is considered as unchanged. In this perspective, the artifact is considered to amplify the system's functional capacities;

- a "personal" view, which is that of the user from whose perspective the transformations of the task are examined. These transformations of the task bring about new cognitive demands that necessitate the activation of cognitive capacities very different from those required by the original task.

Norman thus develops a hypothesis of a recomposition of the activity as a whole also using a triadic model to understand activities with cognitive artifacts. Here he joins the hypotheses of Vygotsky, who is cited in the bibliography.

An attentive reading of Vygotsky's texts reveals that he too uses a triadic conception of activity with instrument situations, even if he does not present this in graphic terms (at least in the texts to which we have access). He distinguishes three poles of the Vygotsky triad (1930): a new intermediary element, the psychological instrument, places itself between the object and the psychic operation directed at it.

We will return to his definition of the psychological instrument. Let us note only that it is by analogy with material instrument usage situations that

Vygotsky elaborates this triad. He hypothesizes a recomposition of the whole activity linked to instrument usage that leads to the emergence of the instrumental act as a pertinent analysis unit for psychology. He shows that tools and signs share a mediating function, yet indicates the limits of the analogy and their differences, particularly in the way they orient human activity (Vygotsky 1931).

A triadic approach to activity with artifact situations is also developed in the domain of process control. Hollnagel (1990) also identifies three pertinent poles: user, computer and process, while distinguishing two types of interactions (see fig. 10):

- the computer supplies the user with information on the process and at the same time "amplifies" some of the user's cognitive functions (discrimination, interpretation). The relation is one of embodiment in that a computer can be in a certain way considered as a part of the operator (Ihde 1979);

- the computer is an interpreter of communications between the operator and the application program. It is a mediator over which the operator has no control. The relation is hermeneutic. Hollnagel links this distinction to that established by Reason (1988) between tools that correspond to the amplifying function and prostheses that interpret.

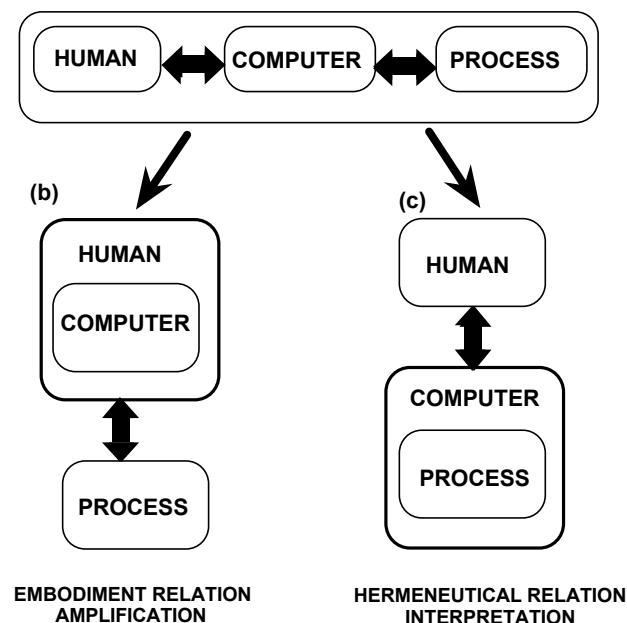


Figure 10 Hollnagel's tripolar model (1990)

Discussion on the appearance of a forth pole

An initial conclusion is that the triadic scheme is liable to a wide range of interpretations linked to viewpoints that are themselves different, though coherent in themselves. This is not at all problematic as long as these viewpoints are made explicit. The triad is very general in nature: it underlies interpretations in very different disciplines, from technology and engineering to

cognitive psychology via animal psychology, psycho-sociology and ergonomics (including cognitive ergonomics).

This generality is a very interesting feature in itself: the I.S.A. modeling that systemizes it can, like the notion of the instrument, take on the status of **intermediary concept**, facilitating inter-disciplinary dialogues as well as cooperation in action. It indicates an approach common to several disciplines whilst being interpreted and interpretable in a specific manner for each of them.

The second discussion point concerns these different interpretations among disciplines (and often also within the same discipline), without limiting ourselves to the examples that have been presented.

We feel that conceptions of the subject pole of the triad are on a continuum which runs from positions that strongly affirm the idea of a subject as carrying signification and acting intentionally in a socially finalized environment to conceptions in which the very notion of the individual or the subject seem to break down:

- either because the subject is no longer considered as a human component or factor (whose properties must be identified so they can be taken into consideration: he/she is, for example, the center of intelligent processes) in a more global system including technological components (which in some conceptions may have an equal status, for example being also the center of intelligent processes);

- or because the individual subject tends to recede before the idea of a collective subject when the aim is to identify the collective dimensions of the action.

A systematic and detailed analysis of these different positions on the human pole of the triad and their evolution in the history of ideas remains to be done. It will no doubt generate vital debates. We need only to remember Bruner's assertions (1991): a violent, anti-mentalist campaign against the notion of the agent implying that behavior occurs in the grip of intentionality in relation with desires, beliefs, moral obligations, etc., was carried out at the beginning of what can be called the "cognitivist revolution". We should also remember that the term "operator" comes from the notion of operation, which has a known status in Taylorism, even if it has taken on other meanings since then.

As for conceptions of the instrument pole¹⁵, it is enough to stress that most authors give it an intermediary, or even mediator status between the subject and the object. This implies a break with the usual bipolar models in psychology (as well as in other human or life sciences), reducing situations to a one-to-one interaction between the subject and all that is not subject: the social environment, the environment associated and even blurred into the

¹⁵ We will only vaguely develop conceptions concerning the instrument pole of the I.A.S. model here because the notion of the instrument will be more fully analyzed in the following section.

object. Yet the intermediary status concerns very different artifacts (from sensori-motor systems to signs and languages via sticks, machines, computers and expert systems) which are themselves apprehended in different ways (inert artifacts, functioning active artifacts that may be centers of intelligent processes).

The status of the object is also interpreted in a range of ways (material object, process, virtual object, object of thought or even behavior specific to the subject or other subjects). However, major distinctions common to authors of several disciplines can be identified. The first consists in identifying in the object that which has the status of object of the activity or action, i.e. what it focuses on, other aspects of reality which are significant for the activity and form the context or environment. The second concerns the type of possible relations to the object: relations of knowledge, transformation (or both) and finally of communication (particularly when the instruments are symbolic).

One of the most striking aspects thrown up by the comparison of these different interpretations of the triad is that depending on the reference situations and points of view adopted, the operator can occupy each of the three poles: he/she can of course be the subject, but also the instrument (his/her own instrument or someone else's) and even the object of an activity turned toward him/herself (by him/herself or by someone else). The different poles may be occupied by different operators or by the same person simultaneously or successively (for example in conceptions by Vygotsky or Bullinger).

Finally, contemporary technological evolutions have brought about the appearance of a forth pole to describe the new situations linked to the emergence of software programs for collective work (groupware)¹⁶. These new types of devices are specifically oriented toward collective dimensions of work. They aim to allow and facilitate shared work. Interactions between the subject and other subjects, collaborations and cooperation are added to the usual relations between subjects, objects and instruments¹⁷. The tripolar model thus becomes a quadripolar model (fig. 11)

¹⁶ This enrichment of the instrument-mediated activity situation model owes a lot to our discussions with Yves Clot, as well as to research by Pascal Béguin (1994) to whom we will return later.

¹⁷ In a recent study (1994), Béguin lays out the important characteristics of these interactions between oneself and others via the instrument, thus performing a function of collaborative mediation to reach common goals within collective activities.

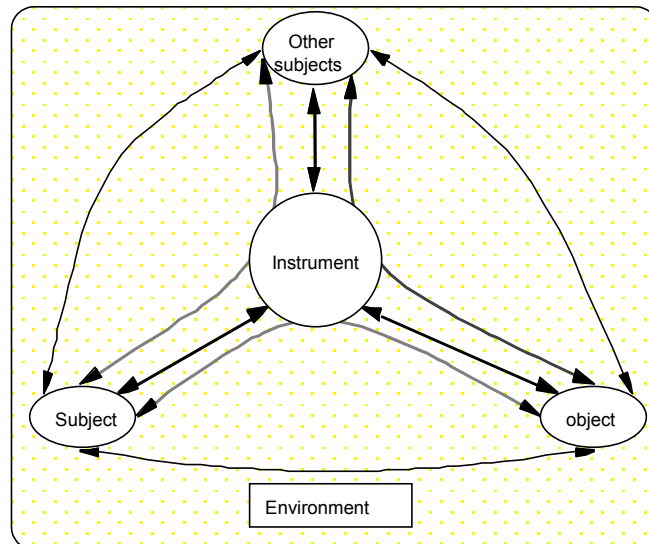


Figure 11: C.I.A.S. model Collective instrument-mediated activity situations

Our last point concerns interactions among the poles of the triad. One of them, the subject-artifact interaction, is omnipresent. Even when it seems to disappear, as in the situation where the artifact has an amplifying status, an incorporation relation (Hollnagel) remains. For most authors, there is then the artifact-object interaction. At times this may not be made explicit, particularly in situations in which the object has an internal position in the artifact (computer, process). The accent is then placed on the relation to the object, mediated by the artifact, while, for obvious reason, direct subject-object interaction disappears. This interaction may also not appear, particularly when the triad is considered from a technocentric perspective.

CHAPTER 5: POINTS OF VIEW AND HYPOTHESES ON INSTRUMENTS

Above, we explored different types of possible relations to artifacts and showed that the instrument is not a given, but rather the result of associating the artifact with the subject's action as a means for this action. Yet this perspective, whilst shared by some of the authors who have looked at instruments, is not the only one possible. Conceptions, as we have seen, vary enormously¹⁸.

First, we will present the different conceptions in light of the viewpoint we have considered as dominant, then we will put forward an overview.

¹⁸ In some cases, when this opposition is meaningful for the authors, we will differentiate between the terms instrument and tool. In all other cases, we will use the term instrument.

Technological Approaches

For predominantly technological approaches, definitions are primarily focused on function: object considered in terms of its function; functioning control devices of various organs of a machine; or on the action modalities on matter. The tools used in mechanical machining, for example, fit into three classes: cutting, sanding and deforming matter.

The terms instrument and tool most often distinguish classes of technical objects. Again using the example of machining, instruments are generally oriented toward information gathering and tools toward transformation. Yet these distinctions are not consistent and vary among domains: for example, we speak of surgical or musical instruments. The main feature of these conceptions is that they focus on technical systems and refer only vaguely or not at all, to the activity of the subject using the instrument. The user may even be ignored altogether.

A biological metaphor

The viewpoints developed by Simondon (1968 and 1969) fit into of a broader perspective, aiming to apprehend human relations with their social environment, mediated by technical objects and more generally, by techniques. He distinguishes instruments from tools by analogy with biological organs: the tool is a mediator for action anticipated by an operator possessing knowledge. It extends and adapts organic effectors. The instrument is the opposite of the tool. It extends and adapts sensory organs. It is a captor and not an effector. It gathers information, whereas the tool serves to exercise an action.

For Simondon, the tool and the instrument mark the emergence of mediation between the organism and the social environment. The primitively binary relation becomes ternary by its insertion in the medium-term. The relationship as a whole falls under the term relational function: the essence of the mediator is constituted by the coupling of organism and social environment¹⁹. For Simondon, the technical object (in its tool and/or instrument modalities) is a paradigm of the relation between living being and social environment. This conception introduces the subject but in a viewpoint that is external to him/her: as an organism and like one of the two terms of the pairing carried out by the mediator. The viewpoint remains thus primarily focused on the technical system, rather than on the subject and the biological metaphor here is revealing.

The animal's instrument as an intermediary world

Guillaume and Meyerson's research options are completely different in that they seek to analyze instrument use among monkeys and thus determine similarities and differences with human use. While Simondon's notional reference is the biological metaphor, Guillaume and Meyerson consider the

¹⁹ Simondon's approach is thus related to the functional analysis developed in technology.

instrument and different types of instruments in light of activity. From their first studies, they affirm that the instrument (a stick) is not merely an extension of the arm allowing the subject to reach a desired object. Rather, it is the means that allows the performance of the specific activity of operating a detour (for example, reaching a piece of fruit that an obstacle prevents from being attained directly).

In Guillaume and Meyerson (1931), the definition of the instrument is clarified via intermediaries linked to the object (for example, a string attached to a piece of fruit): "the simplest instrument an animal can use to pick up an inaccessible object is a material intermediary with one part, or its extremity, in the animal's field of action, and the other part joined to the desired object". This definition raises the question of the status of the mediator, or intermediary between acting animal and desired object.

However, the authors stress that it is not an instrument in the full sense of the word: a string attached to a piece of fruit can be, for the animal, no more than a long tail to pull on; the intermediaries linked to the object are thus on the level of instrumental function. Guillaume and Meyerson (1934) affirm that the true instrument is independent of the present situation, of the bait and of the objects it must be applied to: it is valid for thousands of possible situations, similar or dissimilar. In the case of the intermediary attached to the object, the link exists. It merely needs to be exploited. In the second case, it remains to be established and constructed: an object that is not currently attached to the goal must acquire a link, in certain conditions that must be understood and anticipated. The free instrument is neither a simple extension of the members, nor an extension of the object. It is an object whose properties can be seen both independently of those of members and associated with those of members.

Thus, for the animal, and it would seem for man, the instrument is a sort of intermediary world whose properties are, or can be different both from those of the body and those of the objects on which the action is exercised. In order to act efficiently, one must be able to associate these diverse properties in more or less variable situations.

For Guillaume and Meyerson, as for Simondon, the instrument is thus an intermediary world. For the former, however, it is between the subject and the world, whereas for the latter, it is between the organism and the social environment. We can only stress the extent to which Simondon's biological metaphor, used alone, is simplistic. If the instrument must indeed be considered as an intermediary world, it is not only for an organism but for a subject, a psychological and social subject all at once, who does not act in an undifferentiated social environment, but on the objects of his/her activity.

The social instrument, capitalizing on experience

Wallon's remarks (1941) are in line with this. He compares the human instrument to that of monkeys based on a viewpoint focused on activity: primitive or elaborate, banal or specialized, an instrument is defined by the uses attributed to it. It is fashioned for them. It imposes its operational mode on whoever wishes to use it. It exists durably and independently. Those who know

of its existence can mobilize it when they need to. The instrument is a constituted object, an object constructed following certain techniques in light of other techniques and the reworked product of traditional or recent experiments, the fruit of which is transmitted by those who use it.

According to Wallon, this strong individualization does not apply to the chimpanzee's instrument. It is not only occasional, but a simple part of a provisional whole from which it takes all its signification. If the stick the chimpanzee uses to bring a piece of orange or banana toward itself is not perceived exactly when it attempts to reach them, it will remain useless and ignored. The animal's instrument is only an instrument in so far as it is perceived, and it is perceived only when it is dynamically integrated into the action.

Here Wallon affirmed more than he could prove and even contradicted the last affirmations of Guillaume and Meyerson (1937) who had identified in some cases behavior that retained the instrument. Yet we find in Wallon's research an idea also developed by Vygotsky and above all, Leontiev, of a capitalization of acquired experience in the human instrument and thus, a possible transmission of this cultural capital. The instrument is not only an intermediary world and a means dynamically integrated into the action, it is also capitalized experience and knowledge.

For Leontiev (1975, 1976), the instrument must be considered as a carrier of the first real abstraction: in direct subject-object interaction, the object's properties are only revealed in the limits of the subject's sensations, whereas in the interaction process mediated by an instrument, knowledge goes beyond these limits. Thus, when we fashion an object with another object, the deformation of one of these objects leads us to deduce that the other is harder. A practical analysis is thus carried out and the properties of objects on which we act using the instrument following criteria objectified in the instrument itself is generalized.

For Leontiev, instruments are the means of human activity. The origin of this activity must be sought in work. An instrument cannot be considered outside its connection with the goal. Otherwise, it becomes abstract (in the critical sense of the term in this case) in the same way as an operation considered outside its connection with the action it carries out. The instrument-goal relation is thus considered as constituting the very notion of the instrument.

We will not come back to hypotheses relative to the crystallization of experience in instruments and the social process of appropriation by which it is transmitted and which make the instrument a material precursor of signification. We will merely highlight that what is central for Leontiev, as for most of the authors mentioned above, is the subject. Yet the subject is not locked into a solipsistic relation with instruments and more generally with artifacts: the individual's relations with the world of human objects are mediated by relations with other people.

This is why he criticizes attempts to cast aside perspectives focused on the human subject: "we attribute properties of authentic subjects of thought to

thinking machines of our era. We thus present things as though it were not machines that were the instrument of human thought, but humans as instruments of machines."

From the material instrument to the psychological instrument

In this, Leontiev joins Vygotsky (1930, 1934) who developed a generalized psychological conception of instruments focused on the subject. For Vygotsky, instruments allow not only the regulation and transformation of the external social environment, but also the regulation, by the subject, of his/her own behavior and the behavior of others.

Language, signs, maps, plans and diagrams are considered as psychological instruments that mediate the subject's relationship with him/herself and with others. The psychological instrument is thus differentiated from the technical instrument by the direction of his/her action turned toward the psyche. The integration of the instrument into the behavioral process calls upon new functions linked to the control of the instrument, replaces "natural"²⁰ processes performed by the instrument and transforms the order and particular aspects of the psychic process. These processes occur within a complex structural and functional unit: the instrumental act.

The viewpoint developed by Vygotsky consists in both distinguishing instrument types based on what they allow the subject to act on (the material world, his/her own psyche or that of others) and proposing an analysis unit of instrument-mediated activities: the instrumental act.

The instrument is thus doubly apprehended in terms of the subject. Yet Vygotsky's approach is interesting not only because of the association of notions of instrument and instrumental act. It is even more fundamentally linked to the very notion of the psychological instrument by which the subject controls and regulates his/her own activity. The psychological instrument, which may have an existence external to the subject, also has an internal existence that allows the subject to manage him/herself by him/herself. Thus semiotic instruments (language, maps, etc.) are not only instruments of knowledge (cognitive instruments according to certain authors, see p 75). They are also psychological instruments.

The instrument as indicator of child development

For Grize (1970) who wrote the preface to Mounoud's study, the instrument also has a psychological content: it is knowledge and participates in both the object pole and the operational pole due to its intermediary status. Yet if the instrument is knowledge, this point of view differs from that of Wallon, Leontiev or Vygotsky who considered it to be capitalized, crystallized knowledge that is the fruit of acquired experience transmitted via the instrument. Grize's instrument reflects the epistemic state of development of

²⁰ A simple example is a knot in a handkerchief to remind us that we have to do something.

the child, thus following the child's conception of the instrument means following the evolution of his/her knowledge.

This is precisely what Mounoud (1970) aimed to do in seeking to identify conceptions of instruments specific to each age. He defined the instrument as any object that the subject associates with his/her action to carry out a task. The instrument extends and/or modifies this action and has characteristics that are simultaneously associated with the subject's actions and the objects to which it is applied.

Mounoud's definition sums up in part, beyond his own studies, the research carried out by his predecessors (particularly Guillaume and Meyerson)²¹. Based on this initial definition, Mounoud distinguishes two categories of instruments: those which transmit subjects' actions without transforming them and those which transform them by inversion, reduction, etc. The instrument is thus an intermediary world between subject and object: it associates itself with the subject's actions; it maintains relations of complementarity with the objects (and the context of the task) that it applies itself to; and finally, it replaces some of the subject's actions in carrying out their functions.

For Mounoud, the instrument is simultaneously content in terms of the subject's action and form in terms of the objects it is applied to. Instrumental behavior thus introduces several forms of dependency: between the subject's action and the instrument's movements (hooks, poles, angle rods, etc.), between the instrument's properties and the device, between the various parts of the instrument, etc.

While Mounoud sees the instrument as an intermediary between the subject and the object, the object is exclusively a material object on which transformations are performed. In this, his conception is similar to that of Simondon who considers the instrument as a mediator. But for Mounoud the subject remains the main point of reference. It is in terms of the subject that the instrument is defined, i.e. the means that the subject associates with his/her action. This is an essential difference from Simondon who refers primarily to the technical system and its coupling with the organism and social environment.

Finally, in the conclusions of his experimental research, Mounoud stresses that for subjects, instruments are classes of equivalence: they both satisfy conditions that make them equivalent in terms of experience. Mounoud distinguishes between the extension of the instrument (its ability to adapt to all sorts of situations) and understanding (of the instrument's properties). The

²¹ For many authors, Mounoud's definition is a departure point for their own reflections. Leplat and Pailhous (1973), for example, start with Mounoud's definition of instruments as intermediaries with their own functioning rules and develop an analysis frame of intellectual activity in work on instruments concerning, in particular, representation and handling systems constructed by operators. Also starting with Mounoud's definition, Guillevic (1990) examines the cognitive appropriation of the tool as a condition for reliability in technology transferring situations. The appropriation concerns all the internal processes activated in the subject in these situations. He too considers the tool as a mediator between the operator's action and the workplace.

evolution of the instrument with genetic development occurs via a reduction of extension and an increase in understanding.

The semiotic instrument

We also find the idea of classes of equivalence in Prieto (1975) who describes the class that makes up a particular tool and all others with the same use (i.e. those that allow the same operations to be performed) as "operants". From 1966, Prieto, a semiological researcher, considered semiotic systems as instruments. We can only be struck by similarities with Vygotsky, to whom he had no access (a collection including a text by Vygotsky on the instrumental method was only translated into Italian in 1974).

For Prieto, the instrument confers the possibility of acting on the outside world. This is its *raison d'être*. It is produced deliberately so as to carry out certain determined operations. It provides classes of objects, i.e. concepts and classes of operations that are also concepts. Instruments whose function is to transmit messages are signals. They allow an influence to be exercised over that which surrounds people. Like any instrument, signals supply people with concepts constituted by their respective signifieds.

In a text from 1975, Prieto uses the word tool to describe what he previously called an instrument: the individual object that in the instrumental act (i.e. the execution of any and every operation) plays the same role as that played by the signal in the semiotic act. He reserves the term instrument to designate the entity constituted by an operant (the class formed by a determined tool and all those with the same use) and the corresponding use.

Despite similarities in vocabulary, Prieto's approach is thus very different from Vygotsky's. His analysis is almost technical: he analyzes the instrument as such independently of the way it exists for the subject (the interiorized instrument) and the activity he/she undertakes so as to use it. Clearly, he is not interested in the subject's global activity into which the use of the instrument fits. This type of analysis is necessary in order to know the "objective" properties of semiotic instruments (just as a technical analysis of machines reveals their technical properties), but it is insufficient for both psychology and ergonomics, both of which are concerned with the interiorization of these properties and the insertion modalities of instruments in activity.

The main difference between Prieto and Vygotsky lies here. It is particularly apparent in their divergence on the point of the main action: for one, it is the subject's control of him/herself and others, for the other, the transmission of a message (even if both also envisage another pole). Finally, Prieto does not seem to contemplate the full recomposition of the subject's activity in and by the instrumental act.

The specifically psychological dimension thus escapes Prieto (who has no ambition in this field). Yet the positive feature of his approach is that via a systemization of concepts, he gives weight to the analogy, hitherto a little metaphorical, between material and semiotic instruments. He thus allows the generalization of essential ideas in semiology: the idea that every instrument, like every sign, is a bifacial entity. This idea is shared by authors interested in

problems as diverse as the writing of users' guides for instruments of daily life (Legrand, Boullier & al. 1991) or the construction of psycho-semiology (Cuny 1993)..

Cuny (1993) focuses on the subject and more specifically the subject engaged in action. He defines semiotic tools²² as objects whose role is to provide information and which are part of the user-task system typical of every work situation in participating in determined operations within which these semiotic tools are functional. Like all instruments, they are indissociable from techniques and the operational modes that allow them to be activated.

Cuny thus shares criteria developed by Leroi-Gourhan (1964) for whom the instrument only really exists as a gesture that makes it technically efficient. Proposing a standardized semiotic tool means presuming the adoption of a determined use technique. On the other hand, looking at the semiotic tools of experienced professionals means discovering products integrated into actions, adjusted to semiotic needs in the evolution of the task-operator relation.

The semiotic instrument assists the operator's cognitive activity by providing information that is useful to action and by guiding the order of the operational sequences. Here, we are close to some of the characteristics of Vygotsky's psychological instruments, including the idea of the semiotic act (Cuny 1981a) which is the equivalent of that of the instrumental act²³. The learning process for a semiotic tool (for example, the electricity schema, Cuny 1981b) cannot be finalized in a purely intrinsic manner: "we do not learn the reading and writing of schemas for themselves but so as to insert them into an operational process". The author's objectives for the psycho-semiology he elaborates are: the analysis of problems of elaborating semiotic instruments, learning to handle them, and beyond this learning, their potential use and functions.

Tools and cognitive instruments

The notion of the cognitive tool developed by Rogalski and Samurcay could seem close to these conceptions. It differs however on important issues. Rogalski (1993) defines the features of her conception of cognitive tools. They are artifacts, objects external to the subject, that result from a social elaboration process and which integrate knowledge (these tools are thus cognitive in nature). Artifacts such as tables of digital data, abacuses, calculators, software tools as well as problem solving methods are cognitive tools.

This is similar to a definition given by Norman (1992) for the notion of "cognitive artifact": an artificial device designed to preserve and present information or process it so as to insure a representative function. Rogalski &

²² In his first studies, Cuny used the term *semic tool*. We will use here the term *semiotic tool* whose use is more widespread today.

²³ These instrumental characteristics, oriented towards guiding the activity, were evoked by Ombredane and Favre as far back as 1955.

Samurcay (1993) insist on the operative nature of the cognitive tools that assume part of users' cognitive activity and thus contribute to performing the task²⁴.

Here we come across an important and old idea: every instrument, tool and machine performs a job and serves the person who implements it (but generally in a professional context, he/she is not the only one to benefit). Taking on part of the cognitive activity often implies a transformation of the subjects' initial representations of the objects of their activity. Thus in the examples given by the authors, the control of forest fires and the operation of blast furnaces, the use of cognitive tools requires the construction of new mental representations of the process coherent with those underlying and constitutive of the instrument.

Unlike Vygotsky's psychological instruments, they are not instruments used by the subject to manage him/herself. Rather, they are tools oriented toward knowledge (usually anticipatory) of objects from reality, external to the subject and toward which his/her (diagnostic, decisional, transformational, etc.) activity is oriented. Furthermore, the collective dimensions of the activity are important here and as Hutchins stresses elsewhere (1990), instruments are not only placed in a context where the operator is isolated and limited to interactions with the tool, in his/her private world.

In a study on collective activities in navigation, Hutchins suggests considering that instruments, along with social organization and members of a collective, form a system of distributed cognition. This supposes not only, as for Rogalski and Samurcay, that instruments carry out part of the cognitive work, but that they are "open", i.e. do not render the work invisible so as to allow both a collective realization and the acquisition and transfer of competence.

However, based on examples and certain hypotheses described as "traditional", Hutchins rigorously questions the nature of the cognitive assistance provided by instruments. For Hutchins, external cognitive instruments that are truly useful to subjects, should not be considered primarily as "amplifiers of information processing capacities", or as "intelligent actors" interacting (cooperating) with operators. According to Hutchins, cognitive tools are good operational aids when they transform the subject's task to give a formulation or representation that is easier for him/her to process. The cognitive capacity of a user-intelligent machine system would thus not depend primarily on the machine's processing capacities but rather the relation between the subject's own resources and the assistance modalities offered by the machine.

In the author's conclusions, this position could move towards the "activity aid systems" perspective developed by Falzon (1989), even if the premises are very different. This hypothesis differs however from that of Reason (1987,

²⁴ The authors' terminology has recently changed in favor (1994) of the term operational cognitive tool, which places greater emphasis on the characteristics they feel are essential.

1990): Reason sees the elaboration of cognitive prostheses (or even mental crutches) as the only possible immediate remedies to the problematic situation created by systems designers. He feels that the systems designed today (and which will continue to be operational for a long time to come) have transformed normal adaptive characteristics of human cognition into dangerous responsibilities. The context of this pessimistic reflection is that of heavy processing industries (chemical, nuclear, etc.) in which the potential consequences of human error are so huge that the "prosthesis" solution seems to him to be the most appropriate.

Nonetheless, the prosthesis solution has major drawbacks as Roth, Bennet & Woods (1987) demonstrate based on experimental data.)

The widespread paradigm of designing expert systems as prostheses aims to produce systems which compensate for human deficiencies. The operator's role is reduced to being a data supplier to the machine. The machine directs the problem solving process and defines the observations and actions that the user must carry out. In this type of user-machine interaction, the machine is in control and the user has a passive role. However, the experiments carried out by these authors indicate that the more the users conform to the passive role of data suppliers, the greater the degradation of the user-machine system.

The authors thus propose an alternative to the "prosthesis" paradigm: an instrumental conceptualization of cognitive tools. Cognitive tools must be conceived as instruments at the subject's disposal so he/she can resolve a problem. The cognitive tool plays the role of a consultant, a source of information for the subject who directs the problem solving process. The user's role is to watch over the performance of the user-machine cooperation as a whole in managing the range of cognitive resources at his/her disposal. The user is in control.

Roth, Bennet & Woods, like Rogalski & Samurcay, Hutchins or Falzon, insist on the primacy of the subject's activity. It is this activity that must organize the interaction with the cognitive tool, which supposes that the subject controls it. This position founds the instrumental paradigm alternative to the prosthesis paradigm.

Thus the necessity of an instrumental point of view on artifacts is raised, even when these artifacts are based on the most contemporary technologies such as artificial intelligence.

Summary: the instrument as mediator, knowledge, operant and means of action

Conceptions of the instrument that we explored above are very diverse and at times contradictory. Nonetheless, we will now attempt to extract the main features in order to reach an initial summary of the notion of the instrument.

First of all, an instrument is unanimously considered as an **intermediary entity**, a medium term, or even an intermediary world between two entities: the subject, actor, user of the instrument and the object of the action.

Here we find the three poles of the triad we analyzed earlier. These poles are considered in a range of ways by our authors. For the actor, conceptions are on a continuum and range from the organism (the living) to the subject as an intentional, oriented, socially situated actor. Conceptions of the object are also on a continuum and run from the idea of the object as an environment or social environment to the idea of the object of the activity (the object could be the subject him/herself when the instrument allows him/her to manage his/her own activity).

The instrument's intermediary position makes it the mediator of relations between subject and object. It constitutes an intermediary world whose main feature is being adapted to both subject and object. This adaptation is in terms of material as well as cognitive and semiotic properties in line with the type of activity in which the instrument is inserted or is destined to be inserted.

Two main types of mediation are identified:

- a mediation from object to subject that we describe as an **epistemic mediation** in which the instrument is a means allowing knowledge of the object;

- a **pragmatic mediation** from subject to object in which the instrument is a means of a transforming action (in a broad sense including control and regulation) directed toward the object.

Yet as soon as this mediation concerns a real activity, the epistemic and pragmatic dimensions of the mediation are in constant interaction within this activity.

The instrument is thus not only an intermediary world. It is a **means of action** and more generally, of activity. This is the second feature. Actions are of course very diverse in nature:

- transformation of a material object with a hand-held tool: **material instrument**;

- cognitive decision making, for example in a situation of managing a dynamic environment: **cognitive tool**;

- management of one's own activity: **psychological instrument**;

- semiotic interaction with a semiotic object or with others: **semiotic tool**²⁵.

²⁵ Clearly, definitions of these different "types" of instruments do not define disjointed classes: a semiotic instrument, for example, can allow cognitive decision making (cognitive tool) or contribute to handling one's own or other people's activity (psychological instrument) In fact, one device can

Within the action, the **instrument** is an operant. It is operative in that it takes care of part of the task: it does a job. The nature of this job and what it concerns are obviously related to the objects of the activity and as such, are extremely variable.

The instrument is a specific, situated means of action but it has a much more general aspect. Beyond the specificity of the present, it is pertinent for a class of actions and situations. The instrument is thus simultaneously in a relation of adaptation and independence to the present situation. Some authors even make this independence a criterion for the difference between the human instrument and the animal instrument. The subject thus associates the instrument with his/her specific action, which is dynamically integrated into this action. It is also retained so it can be reused in future situations belonging to the same class or classes. It thus allows durable recompositions of the activity, which are organized into instrumental acts.

Through this preservation, the instrument is a means of **capitalization of accumulated** (some authors say crystallized) **experience**. In this sense, **every instrument is knowledge**.

The knowledge in question is inscribed during design processes and also accumulated by and through a range of situations and uses. From this point of view, an instrument can be considered as a modality of external fixing of acquired human knowledge. A subject may appropriate this knowledge by an adequate activity that must be developed in an appropriate manner²⁶ and, of course, may be elaborated with the help of other subjects (one of the forms of mediation for Vygotsky and Leontiev).

This knowledge is also specific to the subject and characteristic of the forms and modalities of the subject-object relation. It reveals these forms and modalities and as such is a source of possible observables for the psychologist or ergonomist. Knowledge is capitalized both in transformations of the material device that constitutes the artifact and in associated uses.

The instrument is thus, like the sign, which for some authors is merely an individual case, a bifacial and mixed entity of both artifact and use mode, these two dimensions being fundamentally indissociable. From 1965, Leroi-Gourhan considered the tool to be associated with what he calls "mechanical operational chains" acquired by experience and upbringing. He considers that while psychology can apprehend this, it is not pertinent to his own anthropological approach.

CHAPTER 6: THE INSTRUMENT AS A MIXED ENTITY

fulfill a range of functions in the subject's activity. It can be said that there is a synergy of instrumental functions.

²⁶ In order to be truly adequate, this activity supposes that the subject has a perspective allowing him/her to appropriate knowledge.

In the following chapter, we will develop a psychological point of view of the instrument as a mixed entity. We define the instrument as a whole incorporating an artifact (or a fraction of an artifact) and one or more utilization schemes. Yet before giving a psychological definition of the instrument on these grounds, we will examine the concept of scheme based on Piaget's approach. For Piaget, an action scheme is the structured group of generalizable features of the action that allows the same action to be repeated or applied to new contents²⁷. We will then examine the concept of the utilization scheme.

From artifact to usage: utilization schemes

An artifact is not a finished instrument. The tool only exists in the operating cycle, affirmed Leroi-Gourhan as early as 1965. The artifact remains to be inscribed in use, i.e. in activities in which it is a means activated to achieve goals that the user sets him/herself. While these uses are partly anticipated by the artifact's designers, they exceed, sometimes considerably, these expectations. The elaboration and production of uses continues beyond the initial design as private and social production.

We have many examples, such as the use made of photography specific to different social groups identified by Bourdieu (1965) or the unexpected uses of Minitel (chat-lines, sex-lines, etc.). The object, the artifact, the system itself, initially the recipient of a social insertion plan, is in fact inserted into practices that are often different in terms of context and usage finalities (Perriault 1990).

The banal example of the range of real uses of an object as theoretically specific as a hair dryer demonstrates this: drying clothes, defrosting a lock, or even heating a room. However, behind this diversity, we can find relatively stable and structured elements in the user's activities and actions. We have suggested defining them as utilization schemes (Rabardel & V rillon 1985, Rabardel 1991b)²⁸.

Let us take an example borrowed from a study carried out at the *Laboratoire Nationale d'Essai*. During the testing the use of an electric train set, on several occasions the children behaved in a way that placed them at great risk. They tried to introduce electrical low voltage wires into 220-volt sockets.

The authors conclude that the children's ignorance, the presence of electrical wires and the desire to make the device work are behind this

²⁷ As Montangero and Maurice-Naville (1994) indicate in taking the example of prehension, the scheme is not the particular sequencing of movements and perceptions. It is the general backdrop, which can be reproduced in different circumstances and generate a range of productions. For example, the arm is held out at varying angles and the hand more or less opened depending on the distance or size of the object to be picked up. Whatever the object, the prehension scheme is always the same.

²⁸ Guillevic's research (1990), on cognitive appropriation of the tool in a situation of technology transfer also reinforces the idea of the tool's integration into the subject's scheme.

dangerous utilization. We propose a complementary hypothesis that this group of elements (electrical train, wires, sockets) activates a pre-existing "electrical plugging in" scheme among the children. They assimilate the artifact into this scheme forthwith²⁹. This assimilation is both pertinent (it is indeed an electrical plugging in situation) and dangerous in that the child is faced with a range of possible sockets but does not dispose of criteria to choose correctly.

A second example allows us to highlight a situation requiring scheme adaptation. It concerns the type of accident that occurred in the United States when microwave ovens were introduced: a user places a pet in the microwave with the horrible consequences we can imagine.

This accident can be interpreted as an assimilation of a new type of artifact with an elaborated scheme in using an artifact of neighboring usage but with a different functioning rationale. This scheme is based on a use of ovens enlarged to encompass other uses than cooking food. The heating properties of traditional ovens are used to dry objects (such as wet shoes). In cooking with microwaves, *a priori* nothing obliges the user to proceed in a new way. He/she thus assimilates the object to the already constituted scheme. When living creatures are concerned, this assimilation is disastrous. This scheme needs to be adapted on the representation level in terms of heat-generating modalities within the new artifact, i.e. in terms of phenomena causality.

These two examples illustrate the association of utilization schemes and how they assimilate and adapt to artifacts. This association is sometimes so powerful that it cannot be undermined. Thus, all attempts by car manufacturers to change the position of brake or accelerator pedals have failed: in emergency situations, drivers act as if the changes had not occurred³⁰. In order to define the concept of the utilization scheme more precisely, we will now examine, based on the literature, the Piagetian notion of scheme and its contemporary evolutions³¹.

²⁹ Along with Norman (1988, 1992), we can consider that the perceptible elements of the situation call for a certain type of usage or implementation of artifacts. He uses the term "affordance" to describe this type of phenomenon.

³⁰ Let us look at a similar example dating from the start of the 19th century (1801). We will borrow this example from Garneray (1985). On a slave transporting ship, the captain had swapped over the commands at the helm to make more room for the human cargo. Apparently, the men at the helm became used to this new device which was thus adopted. However, during a storm when the ship's survival depended on the precision of a maneuver to be executed immediately, the sailor moved the tiller in the wrong direction and the ship was lost.

³¹ Several notions have been put forward based on different theoretical frames to define the invariants that structure activity and action. This is true of notions of schema, frame, script, scenario, or model proposed by Rasmussen (1983, 1986). We consider them as possible contributions to the definition of what we have chosen to theorize based on a Piagetian framework. This choice allows us to account for the dimensions of the instrumental genesis revealed in empirical research (Rabardel 1991d, 1992 a, Vérillon 1988 c, 1991). We feel it is heuristic for a developmental approach to relations to artifacts. An examination of the literature indicates that this appears necessary to many researchers today: Bodker (1989 & 1991), Engeström (1991), Henderson (1991), Henderson & Kyng (1991), Norros (1991), etc. We need to account for users' production of uses as well as the development of their competence, and elaborate a conceptualization of design processes

Scheme, schema... a nomadic concept

The notion of scheme and related notions (schema, script, scenario, etc.) appear in a number of theoretical frames, not only in cognitive psychology but also in other disciplines such as artificial intelligence, psycholinguistics or social psychology. Furthermore, reciprocal influences among these research fields ensure that these notions and concepts get around³².

Thus the idea of the frame, sometimes used by Piaget in association with that of scheme, and even locally as a synonym of scheme (see, for example Piaget 1936a) was put forward by Minsky (1975) in the field of artificial intelligence after a trip to Geneva. Since then, this idea has been reconsidered by psychology based on this new usage and associated theoretical evolutions.

But the concept of scheme dates back even further. Hoc (1986), for example, quotes as well as the Piagetian notion, the goal anticipation schemes by Seltz (1924) and schemas by Bartlett (1932). Eysenk & Keane (1990) do not hesitate to cite Kant. This concept continues to evolve under the influence of studies in Geneva and more generally, among those whose research aims to capitalize on the scientific progress born of the Piagetian paradigm (Cellérier 1979, 1992, Boder 1982, Bastien 1987, Vergnaud 1990 a & b, etc.) and also in relation with artificial intelligence and psychological theories linked to the information processing paradigm.

Several authors have already carried out analyses of different types of conceptions that intersect and sometimes collide over the notion of scheme, particularly Cellérier (1979 a & b), Hoc (1986), Bastien (1987), Hoc & Nguyen Xuan (1987), Fayol & Monteil (1988), Richard (1990) and Eysenk & Keane (1990). We refer readers to these studies and content ourselves with summing up the main features, in focusing particularly on aspects that we consider pertinent in an instrumental perspective.

The concept of scheme is absolutely central in Piagetian theory, yet in the 1960s, although the essential properties of schemes were defined, the concept was insufficiently formalized to satisfy programmability criteria for computer systems. This is one of the reasons, as Cellérier (1979 a) reminds us, of its rejection in the Piagetian form by part of cognitive research born of the information processing approach.

Thus Moore & Newell (1974 a) consider that assimilation and adaptation concepts and theoretical notions like that of the scheme are insubstantial in computer terms. Related conceptualizations aiming to satisfy computer criteria were thus developed and during the same period, other authors sought to bring together conceptualizations born of Piagetian theory and that of information processing: Pascual-Leone & al (1978), Fischer (1980), Cellérier

that allow an understanding of users' contribution to design and facilitate acknowledgement and integration of this by design professionals.

³² In the evocatively titled work "From one Science to Another: Nomadic Concepts", Stengers (1987) unfortunately does not look at the concept of the scheme, despite its long and itinerant history.

(1979 a & b, 1987), Cell  rier & Ducret (1992 a & b) in particular. For the first two, we refer to Bastien (1987) who presents a detailed analysis. We will also develop Cell  rier's propositions (which also influenced Bastien) as they seem particularly interesting from our standpoint. The Geneva researchers continued their work around Inhelder and Cell  rier inspired by the renewal offered by the latter. We will come back to this. Finally, theoretical elaborations were developed in relation with the acquisition of scientific knowledge (for example Bastien in 1987 or Vergnaud 1990 a & b). We will also come back to this.

Attempts to formalize the scheme concept in the frame of the information processing paradigm produced several notions that are often very similar to one another as Hoc (1986) indicates.

Minsky (1975) seems to be the first to have attempted a formalization of the declarative aspects of the scheme in the domain of form recognition. Purely ascendant undertakings (directed by data) for the analysis of a geometric configuration turn out to be fairly inefficient. The author proposes activating knowledge on the invariants of common structures (prisms, etc.). These invariants, called "frames", once called upon constitute waiting or hypothesis systems to recognize the stimulus presented. Applying the frame consists in particularizing the schematic description given by the frame.

Most authors formalize schemes in the same way as relational systems between variables to be particularized (assimilation)³³. Hoc & Nguyen-Xuan (1987), consider that frame, script and schema concepts are the same. They are a reference for interpreting new data. The reference frame can be an event, an object or a concept: it is always generic knowledge constructed via a certain number of experiences. A frame is a structure of variables. Interpreting new data means specifying the values of the variables.

The most important properties of frames are:

- inference by inheritance: "specific case of" relation (e.g. restaurant = specific case of commercial establishment);
- understanding directed by concepts: inference of non-perceived data that can lead to an orientation toward another frame if incoherence is observed between frame hypotheses and data;
- representation of procedural knowledge: there are variables to which are attached specification or problem solving procedures;

³³ Moore and Newell (1974) put forward a beta-structure for very new objects allowing a vaguer assimilation by analogy. For Schank and Abelson (1977), schemes are formalized in the form of scripts corresponding to a stereotyped sequence of events, which explains difficulties in treating unfamiliar situations. Schank (1980) put forward a hierarchical organization in MOP (Memory Organization Packet) constructed by abstraction and generalization based on scripts. The information memorized from a specific script is limited to that not belonging to the highly ordered MOP. For Sacerdoti (1977) a plan is a schematic representation corresponding to a breakdown of the structure of the goal in the preceding stage, in line with the introduction of constraints or general heuristics.

- interlocking of frames: a variable can be a frame.

Most formalizations of the notion of schema deal with relations between declarative and procedural knowledge. The assimilating schema that serves understanding contains procedural attachments allowing the treatment of data that has particularized the schema. According to Hoc (1986), these formalisms only deal with limited aspects of the assimilation-adaptation mechanisms but allow the reintegration of understanding in problem solving³⁴.

As Hoc (1986) stresses, the definitions given by artificial intelligence appear more precise and more operational in a context of constructing the most efficient possible technical systems. This however, is not the aim of cognitive psychology, which aims at constructing valid models for broad classes of situations, as the author reminds us.

Indeed, the schema concept is not a simple formalization of the scheme concept as Richard (1990) demonstrates. Nonetheless, action schemes and schemas are similar in several essential ways:

- the scheme is reproducible: it contains recognition conditions for the situations it applies to. The action scheme also contains information concerning its application conditions, which constitute prerequisites for its sub goals;
- the scheme assimilates: it applies itself to new situations. The action scheme can also allow generalization to other situations by analogy;
- the scheme is teleological in nature, which gives it a control system and allows it to assign functional signification. The schema also contains information on the goal, which is at the heart of functional meanings that make up the functionality network.

But for the author, the major difference is that the scheme does not constitute declarative knowledge. It applies itself autonomously and does not need an action programming mechanism like the action schema. On the other hand, action schemas are declarative knowledge whereas procedural knowledge particularized for certain contexts is, like schemes, directly operational and immediately executable. Richard thus thinks that the Piagetian notion of scheme must be broken down into several notions to disassociate them from inference and evaluation schemes.

Our aim is not to feed the theoretical debate around the notion of scheme but to define utilization schemes to construct a psychological definition of the instrument. However, we feel that some of the evolutions in the notion of scheme put forward by the Geneva researchers tend towards a differentiation of the notion that seems necessary to Richard. We are particularly interested in the distinctions between presentative and procedural schemes, the schematic specification process described by Inhelder & Caprona (1992),

³⁴ It is on these grounds that Richard (1990) defines comprehension: it results from the particularization of a schema.

between familiar and unfamiliar schemes and procedures put forward by Boder (1992), and the different meanings of familiar schemes: routine, primitive, procedure, analyzed by Saada-Robert (1985, 1989, 1992).

The current orientation of the Geneva school's research, which now focuses on studying the functioning of the psychological subject in problem solving and action situations rather than the structures of the epistemic subject is at the origin of these developments. We will present the essential aspects but first, we will explore the notion of scheme developed by Piaget.

Piaget's notion of the scheme

For Piaget (1936a), who analyzed the birth of intelligence in its sensori-motor dimension³⁵, schemes constitute means that allow the subject to assimilate the situations and objects with which he/she is confronted. They are the structures that prolong biological organization and share with the latter an assimilating capacity to incorporate an external reality into the subject's organization cycle³⁶: everything that meets a need is liable to be assimilated.

The scheme, means of assimilation, is itself the product of assimilating activity: psychological assimilation in its simplest form is only the self-preservation tendency of all behaviors. It is reproductive assimilation that constitutes schemes. These schemes come into existence as soon as behavior, however simple, gives rise to a repetitive effort, which schematizes it. The action scheme is thus a structured whole of generalizable action characteristics, i.e. those which allow the repetition of the same action or its application to new content (Piaget & Beth 1961).

The scheme is an active organization of first-hand experience that integrates the past. It is thus a structure with a history and is progressively transformed as it adapts to a wider range of situation and data. A scheme is applied to the diversity of the external environment and is generalized in line with the contents it is applied to. The history of a scheme is that of its ongoing generalization as well as that of its differentiation:

- schemes, once constituted, serve as instruments for the organizing activity. They allow the subject to assign goals to actions, to be the means of these, and to attribute a signification to experiences. New objects assimilated by schemes thanks to their similarity of appearance or situation are thus attributed meanings, as they in turn contribute to the extension of these meanings and the formation of new signification networks;

- schemes adapt to external reality which they have difficulties assimilating and they also adapt to other schemes. Adapting is one of the sources of progressive differentiation. The other source is the application of a range of schemes to one object. Adaptation, reduced to a simple overall

³⁵ Piaget also calls intelligence practical sensori-motor intelligence.

³⁶ Later, Piaget spoke of self-organization. See, for example, 1974 a & b.

adjustment in the first months of life, then gives rise to directed explorations and more and more precise experimental behavior.

The evolution of schemes, and the subject, thus follows two complementary processes: one incorporates things into the subject, the assimilation process; the other is adapting to things themselves.

Every scheme constitutes a whole, i.e. a group of mutually dependent elements that cannot function without each other: they are mutually implicated. This is the overall signification of the act that insures the simultaneous existence of relations that constitute the schemes as a whole.

Although they originally make up isolated wholes, schemes coordinate themselves by reciprocal assimilation into new, original and broader wholes that also have shared properties. Thus, in a small child, the coordination of several schemes is a unique act resulting from the need to attain a goal not directly accessible via an isolated scheme. This implies the mobilization of schemes hitherto relative to other situations and their coordination resulting in the formation of a main action scheme incorporating a more or less long series of subordinate schemes.

Let us look at an example in Piaget's observations (1936a) in which he analyzes the birth of intelligence. He analyzes the acquisition of the use of a stick in young children (just over one year old). The child is sitting opposite a sofa on which is placed a small jug she wants to pick up. Next to her is a stick that she played with in the preceding weeks, hitting the ground and objects. She first tries to reach the jug directly, then picks up the stick and hits the object with it. By chance, it falls. A little later, the jug is on the floor (and thus cannot fall). She hits the jug again with the stick and watches the movements attentively. She progressively starts pushing the jug with the stick and ends up bringing it within her reach. Finally, in another situation in which no stick is available, she picks up a book to use it like the stick and tries to bring the desired object into reach.

Thus the child initially tried to use an already constituted scheme (hitting with a stick) but this assimilation of the situation does not allow her to succeed each time. The scheme will thus be progressively adapted so as to manage the movement of the object until a new scheme is formed: pushing with a stick. Finally, this scheme is extended to other objects, in this case, a book. The new behavior formed is finally underlain by a main scheme that incorporates a series of schemes: picking up a stick, pushing with the stick, picking up the desired object.

This pedagogical example should not imply that schemes only concern sensori-motor activities. For Piaget, schemes are also at the origin of concept formation, as indicated by a series of studies on awareness and differentiating between "succeeding" and "understanding" (Piaget 1974 a & b). In his research on awareness (1974 a), he stresses that at first, only two elements of the action are conscious: the goal and the result obtained. The first depends on the assimilating scheme in which the object is inserted and the second depends on the object itself. Awareness of means emerges based on the object's observables, i.e. analysis of results. Reciprocally, the analysis of

means, or the action's observables will provide the subject with essential information on the object and gradually, the causal explanations of his/her behavior.

Thus Piaget sees the awareness mechanism as a conceptualization process that reconstructs, then moves beyond (on the level of semiotization and representation) what was acquired to that of action schemes.

For Piaget, action alone constitutes autonomous knowledge of considerable power. Although it is only know-how and not conscious knowledge in terms of conceptualized comprehension, it is nonetheless the source of conceptualized knowledge.

He distinguishes three stages of evolution of the action in genesis:

- the first is that of the material action without conceptualization but whose schemes system already constitutes elaborated knowledge. It is at this level that initial instrumental behavior is constituted;
- the second is that of conceptualization taking its elements from action through becoming aware and interiorizing them as semiotized representations (language, mental images, etc.) but in adding what is new in the concept;
- finally, the third phase (occurring at the same time as formal operations) is that of the considered abstractions operators form based on preceding operations.

At each of these three stages a series of coordinations is progressively constituted by reciprocal assimilation of schemes that are first practical (in the first phase) then conceptual. Awareness thus occurs within the general perspective of the circular relation between the subject and objects. The subject only learns to know him/herself by acting on objects and objects only become knowable through the progress of the actions exercised on them.

This is a fundamental Piagetian credo: the origin of knowledge is to be found in action. However, the focus of his research on the structural dimension of the genesis, while instructive in terms of the construction of the epistemic subject, remained insufficient to account for the behavior of the psychological subject. It was this task that his successors in Geneva worked on.

Cellérier's theoretical elaborations

We will first examine Cellérier's contribution, which we consider decisive, to current thought on the notion of the scheme. We will then look more generally at the studies of the Geneva school to which he belonged. Along with Inhelder, Cellérier was one of its instigators and leaders.

In 1979 he published two important articles that discuss relations between cognitive structures and action schemes in placing this distinction in an even wider debate between two branches of cognitive psychology: the genetic constructivism approach and the information processing systems approach. He considers that far from being opposed, these two approaches

are functionally complementary: genetic epistemology and its heir, genetic psychology, essentially looked at the acquisition of knowledge, whereas cognitivism focused more on its application³⁷.

The two subjects of these theories, the “epistemic” subject and its corresponding “pragmatic” subject as well as the two temporal scales, macro and microgenetic fusion in the individual psychological subject. Yet due to their different focus, the two theoretical systems were the target of symmetrical criticisms corresponding to the dimension that they did not give priority to: if genetic psychology is non effective (in that it is insufficiently formalized to be implementable in computer systems) computer models are non explicative (in that all programs can be interpreted as a network of conditional reflexes and any stronger interpretation must be founded on a theoretical frame necessarily external to the program). Thus, he humorously concludes, critics who a few years ago consulted “theory rats” (European rats always thought without acting while American rats always acted without thinking) today consult the psychological theories of their ex-tamers which after all, is only fair.

Cellérier presents an in-depth discussion of the concepts specific to the two approaches and concludes that the notion of scheme cannot be reduced to the computer approach of formal procedure. He defines a scheme as an internal model that brings together a control structure assembling, during the production of behavior adapted to an external environment, procedural structures based on knowledge forming an internal epistemic problem space. The scheme is conceived as a system subdivided into more specialized modules whose procedures are macro-operators of the problem space that they factorize into independent sub-spaces. The structure is considered to be heterarchic: the different specialized modules, while they are subordinate to the execution of a defined plan in terms of the scheme, interact in subordinating themselves to each other when they encounter, during their own task, a sub-problem for which they are not competent.

The theoretical project of articulation between cognitive structures and action schemes is thus achieved via a formalization of the notion of scheme introducing a modular conception and a heterarchic type control structure.

Cellérier and Ducret (1992 a & b) extend theoretical reflection on the notion of scheme in two complex texts. In this text, we will only look at elements concerning the problem of preservation and differential accessibility of schemes.

Cellérier and Ducret consider the differential preservation of acquired schemes as a functional necessity. Indeed, a scheme’s value is linked to the differential productivity it provides to the cognitive system, i.e. it depends on the sub-whole of other schemes with which it interacts for the same task, in

³⁷ Obviously Céliérier’s analysis is dated and should be placed in the context of debates in the late 1970s. However, we feel it is still interesting today, both because it allows us to situate one of the possible confrontations between genetic and cognitive paradigms and because it is an attempt at capitalizing on their respective contributions. We feel such a capitalization is one of the urgent and necessary tasks facing psychology.

collaboration as well as in competition. Thus certain schemes that are productive during the initial learning phase of an activity are no longer productive at a later phase. They could only be preserved in a reconstruction that would adapt them to their new “fellow workers”. Here we encounter Piaget’s equilibration based on maximal integration of already constructed schemes in a new construction accompanied by a retroactive reconstruction of these schemes.

For the authors, the effect and function of the preservation strategy and integration of acquired knowledge is allowing the production of non-hesitant behavior made possible by anticipatory auto-guidance of both the action of pre-adapted assimilation schemes, and the construction and reconstruction of these schemes by adapting meta-schemes that are progressively better guided by acquired knowledge. As a result, acquired and pre-adapted schemes produce the largely unconscious functioning of the auto-piloting of the subject who brings intelligence to a range of tasks in daily life.

Cellérier and Ducret also put forward the hypothesis that relative priority markers perform the schemes’ differential accessibility and place ongoing evaluation of their relative productivity in the mnemonic organization of schemes. Thus some schemes will be given priority and tried before others. A scheme’s familiarity is therefore partly the expression of differential activation frequency that results from its priority.

The importance of Cellérier’s analyses in an instrumental perspective comes from the fact that the modular approach allows hypothesizing relative to the mechanisms and conditions of the coordination of elementary utilization schemes into complex instrument-mediated action schemes. Also important are the differential hypotheses concerning the preservation and accessibility of schemes. We consider these hypotheses heuristic for the analysis of instrumental geneses (see part 3).

Evolutions of the notion of scheme linked to the functional analysis of the psychological subject’s activity

Inhelder and De Caprona (1992a) in their introduction to a report on the Geneva school’s research on the functional analysis of the psychological subject (Inhelder & Cellérier 1992), highlight the contribution of cybernetics and artificial intelligence in the evolution of Geneva school problematics: reviving the notion of finality, these disciplines caused action to be considered as central to cognitive functioning and to an even greater extent, the teleonomic dimension of action.

As Inhelder and De Caprona (1985) indicate, while in studies of the subject in problem solving situations, main thought structures appear to be the source of general knowledge, they are only the background on which finalized activities take place. These actions are produced by singular individuals with knowledge and know-how born of action and representation schemes and oriented by the resolution of specific tasks. They are produced by **psychological subjects**.

The authors consider the fascinating task of the Geneva researchers to be the progressive revelation of the scheme as a functioning unit responsible for guiding the action.

They distinguish between presentative schemes and procedural schemes (Inhelder & De Caprona 1992 a & b). Presentative schemes seek to understand reality. Procedural schemes seek to succeed in all domains, from elementary actions to abstract problems. These two types of schemes are complementary.

Presentative schemes concern the permanent and simultaneous characteristics of comparable objects. They encompass representative schemes as well as sensori-motor schemes. These schemes do not suppose very elaborate semiotic representations. Presentative schemes can be easily generalized and abstracted from their context. They are preserved even when they are integrated into other larger schemes.

Procedural schemes are series of actions that serve as a means to attain a goal. They are difficult to abstract from their context. Their preservation is limited given that a means to attain a goal is useless when the subject opts for another means³⁸.

Thus schemes are not merely epistemic units that organize general knowledge. They also comprise a practical and finalized aspect that allows them to engender adequate procedures. The scheme is an assimilating frame that attributes signification and exercises a function that manifests itself essentially in planning.

However, there is no direct application of schemes in problem solving. Each context requires that the subject re-specify the schemes he/she disposes of in partially reconstructing them. In order to insure that constituted knowledge is appropriate to a particular situation, schematic specification corresponds to a process of signification attribution that consists in both translating back the transformations allowed by the scheme in line with contextual constraints and recognizing data liable to serve as a support for these transformations. Elements of the situation are thus assigned a function that the subject can use.

In light of a new situation, a scheme has potential that is both indeterminate and rich in actualization virtualities.

The familiar nature of a scheme is not given. It is itself the product of a construction. Familiar schemes are functionally linked to objects or configurations of objects that they organize.

It is this notion of the familiar scheme that Boder (1992) analyzes. It is a scheme in the Piagetian sense (characterized by a genesis and organizing

³⁸ We consider this affirmation to be questionable. In the following section, we develop the idea that utilization schemes, which constitute means, are both preserved (in relation with the utilization of artifacts they are linked to and the objects on which they allow the subject to act) and reinvestment when the subject is confronted with new classes of artifacts and situations.

nature in the context of a situation), which is easily accessible: it is recognized as a special tool in a certain number of situations in which it is selected to organize the work. The consequence of applying these schemes will be that the situation appears familiar to the subject.

For the subject, it is around these schemes that the representation of the problem and the goal is organized. The familiar scheme plays two roles:

- it is an epistemic unit that attributes signification to the situation;
- it is an heuristic tool: it is responsible for the orientation and control of the research.

The scheme's planning function comes from a descendant control. Its realization procedure comes from an ascendant control.

Familiar schemes play a fundamental heuristic role. They are carried out as procedures (much like frames adapt by attributing values to variables) A procedure, during activity, can itself be reinterpreted in terms of another familiar scheme, i.e. it can be given another signification and thus evoke one or more unanticipated schemes. There is thus a relative independence of the familiar scheme and the one or more application procedure(s). This allows, during problem solving, the evocation of new familiar schemes based on a procedure. This possibility is a factor in the evolution of the problem's representation in line with solution attempts and their results.

Let us look at an example from research by Boder (1992). The situation is one of problem solving in which the subject disposes of two jars. The capacity of one is four liters of liquid (J4) and of the other, five liters (J5). The aim is to put two liters in one or the other jar without placing marks on the jar. It is possible to obtain liquid on demand and throw it away. One of the strategies implemented by the subjects (13 to 15 years old) consists in obtaining a liter of liquid (by emptying the contents of J5 into J4, one liter remains in J5) then attempting to obtain a second liter which when added to the first allows them to obtain the result. To do so, they transfer the liter obtained in J5 into J4 so as to be able to fill J5 again and pour it into J4 to obtain the liter they seek. They forget of course that the liter obtained in J4 will thus be lost. Nonetheless, there are two liters remaining in J5, i.e. the solution, which they most often do not realize they have obtained. Furthermore, when their success is pointed out to them, and they are asked to do it again, they have great difficulty.

This comes from the fact that subjects activate a familiar scheme "holding scheme": a liter is obtained in J5 and is held by pouring it into J4. The signification attributed to J4 is being a recipient for contents on hold while another action is carried out using J5. The transfer of a liter of water to J4 is not easily seen in its second property: creating in J4 a new recipient for three liters. The subject has to de-center his/her attention onto the supplement (the recipient of three liters in J4) and thus modify the signification attributed to J4. By this process, a scheme, "supplementary process" progressively takes control of the subject's representation and allows a reorientation of the solving process.

Revealing the more or less familiar nature of schemes is important for an instrumental perspective. We hypothesize that it is the association of familiar schemes (utilization schemes) and artifacts which, in attributing signification to artifacts, objects and the environment, constitutes instruments.

Saada-Robert (1989, 1992) puts forward a complementary idea of equal importance in our perspective: that of a triple association between familiar schemes, transforming instruments (which in the research presented are what we call artifacts) and familiar configurations (houses, walls, etc.) corresponding to characteristic prototypes of things to be made in the task. These three types of elements thus form functional, mobilizable units in problem solving.

She examines (1985, 1992) the mechanisms at play in the microgenesis in situations of problem solving and in particular, the different types of signification that subjects construct. Signification is constructed in relation with the heuristic manner in which the subject breaks down the problem in line with the familiar schemes mobilized. At the same time, this breaking down depends on the significations that the subject attributes to schemes in light of the situation.

Saada-Robert distinguishes three types of signification - routine, primitive or procedure – that a familiar scheme can take on when it is specified in a particular context:

- routine: a scheme is chosen for its overall relevance to the situation. It has something to do with the problem posed and is tried for this reason. However, the exact articulation with the situation is not constructed. The scheme is functionally linked to the object (physical or mental objects) on which it is very dependent. It takes place in a regulated and rigid manner. It is a block. In this case, control is ascendant, i.e. dealt with by particular aspects of the object. Routine corresponds to exploration behavior that best determines the nature of the problem.

- primitive: the scheme is chosen based on its exact signification as a condition necessary to the solution (signification in relation to the goal), and as a key element for the solution because a relation has been established between goal and objects. The functional scheme-object relation fits into the goal-solving by descendant control, which supposes a precise guiding idea. The primitive is mobile, modifiable and composable with others.

- procedures: scheme chosen because of its signification as the most adequate way of transforming the situation. It is a global organization made up of primitives, which can disappear as such. The typical situation procedure allows mastery of the problem.

There can be microgenetic movement from one status to another in the same subject without the order being imperative. There can also be alternative solutions.

The idea that a familiar scheme can take on different meanings seems important to us in an instrumental perspective. We put forward the hypothesis of a genesis of the instrument. The genesis of utilization schemes, which are

one of the components of the instrument, can occur through the reinvesting of already constituted, familiar utilization schemes and their change in signification, particularly when the subject is confronted with an artifact that is new to him/her.³⁹

A development of the scheme concept in acknowledging specificity of content

The contributions of the Geneva school to the theory of schemes are important, as we have just seen. However, despite the growth of domains explored that go beyond Piaget's initial structural psychological approach, these studies have only marginally considered the specificity of behavior in line with the nature of contents. This is an important problem, which has generated studies, particularly in the domain of scientific knowledge acquisition. We will give an example.

Vergnaud (1990 a & b) who put forward a theory of conceptual fields, places his reflection within cognitive psychology, which he calls concepts psychology, thus breaking with traditional Piagetian psychology centered on logical structures. He considers that scientific knowledge is underlain by behavior organizing schemes⁴⁰, and feels that it is in these schemes that we must seek subjects' knowledge in act, i.e. the cognitive elements that allow the subject's action to be operational.

He gives an example in the motricity domain (the scheme that organizes the movement of a high jumper⁴¹) as well as that of mathematical activities. Thus, the counting scheme of a small collection by a five-year-old child, despite variations in form when counting sweets, plates on the table or people sitting spread out in a garden, has an unchanging organization essential for the scheme's functioning: coordination of eye movements and finger and hand movements in line with the positions of objects, coordinated announcement of the numbers in order, cardinalization of the group counted by emphasis or repetition of the last word spoken: one, two, three, four... four! Schemes make up the unchanging organization of the subject's behavior for a class of situations, both in terms of action and symbolic activity.

They concern all types of complex and mathematical behaviors and knowledge, which are themselves underlain by schemes. Thus, the equation solving scheme in the form $ax + b = c$ is highly available and reliable among

³⁹ We have suggested using this possibility of changing the signification of familiar utilization schemes in a design perspective. Identification based on the analysis of usage activities and utilization schemes liable to be associated with artifacts could provide designers with a starting point, which they are often lacking today, in order to anticipate the future activities of users (Rabardel 1991e).

⁴⁰ On this point, we feel Vergnaud is in step with Bastien's preoccupations of formalizing singular schemes (1987).

⁴¹ We would like to stress that generalizing the notion of scheme to adult behavior is not problematic as long as we are in a functionalist perspective and not an approach in terms of phases.

students being introduced to algebra. The rest of their calculations clearly show that an unchanging organization is based on both habits learned and theorems in act such as: “we maintain equality by subtracting b from both sides”. The student’s cognitive functioning comprises operations that become progressively more automatic (for instance, changing signs when we change members) and conscious decisions that allow him/her to take into account the particular values of the situation’s variables.

For Vergnaud, schemes are of the same logic type as algorithms. However, while they are generally “efficient”, they may lack in effectivity, i.e. the property of systematically finding a solution in a fixed number of steps. An implicit or explicit representation of reality is an integral part of the scheme, analyzable in terms of objects, categories in act (properties and relations) and theorems in act. But there is always much that is implicit in a scheme and therefore difficult for subjects to render explicit.

A scheme comprises:

- anticipations of the goal to be reached, expected effects and possible intermediary stages;
- rules of action along the lines of “if-then” which allow the sequencing of subjects’ actions to be generated;
- inferences (reasoning) that allow the subject to calculate rules and anticipations based on information and the operational invariants system he/she disposes of;
- operational invariants that pilot the subject’s recognition of elements pertinent to the situation and information gathering on the situation to be dealt with.

Three types of operational invariants can be identified:

- “proposition” type invariants: liable to be true or false. Theorems in act are of this type;
- “propositional function” type invariants: neither true nor false. These are indispensable bricks in the construction of propositions, e.g. concepts of initial state, of transformation, of quantified relation. They are constructed in action. They are “concepts in act” or “categories in act”;
- “argument” type invariants which adapt propositional functions into propositions.

For Vergnaud, a scheme is thus not a stereotype but rather a temporalized argumenting function that allows the subject to generate different sequencing of actions and information gathering in line with the values and variables in situation.

In our instrumental perspective, the importance of analysis in terms of operational invariants lies in the fact that it allows us to identify the characteristics of situations that subjects truly take into consideration. These

may be familiar situations for which operational invariants are already constituted, or situations in which their elaboration is underway.

Work schemes: an example:

Most of our examples so far have concerned children and we could wonder whether the notion of scheme remains pertinent for describing behavior invariants in adults. To start with, let us stress that Piaget himself progressively extended the field of application of the concept of scheme. In 1955, for example, Piaget and Inhelder introduced the concept of the operational scheme at a formal level, which they considered to be a manner of proceeding or a method. They were no longer looking at children and sensori-motor structures, but adolescents and formal structures. But what about adults and the workplace - that is to say beyond the development periods our authors mostly concentrated on and in contexts typical of social life?

An example borrowed from Béguin (1994) ⁴² will show that action schemes play an important role in structuring operators' activity at work. He analyzes the design activity of an engineering designer in electricity whose task consists of producing a developed schema (technical drawing) based on a logical schema⁴³.

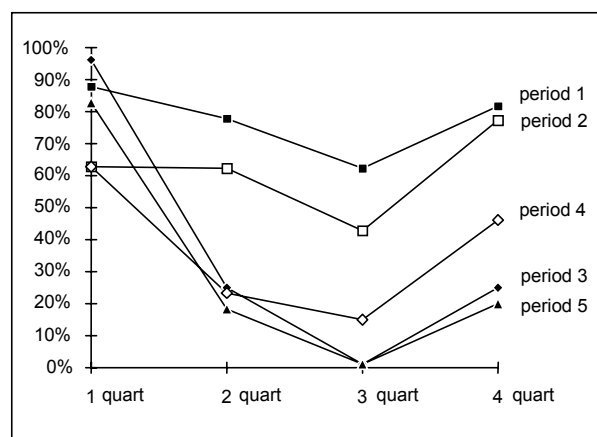


Table 12: percentage of design time devoted to the exploration of the logic schema in line with the different periods and quarters of each of them (based on Béguin 1994).

Five periods, lasting from 52 seconds to a little over three minutes, were identified during production. In dividing each period into four equal parts, we obtain table 12, which concerns perceptive exploration of the logic schema (the source schema for design).

⁴² In his thesis, Pascal Béguin describes an invariant structure of an engineering designer's activity, which we will interpret here in terms of scheme.

⁴³ The logic schema of an electrical installation defines the structure of the installation as a whole and its functioning principles in the form of logic rules, such as "and" and "or", etc. In the schema developed, logic relations are replaced by electrical relations: the schema developed represents an electrical structure with polarities, contacts, receivers, etc.

While the five periods present major differences, they have a related structure:

- in the first quarter of the period, the designer determines the properties that the electrical object being designed must have. He/she is essentially focused on the exploration of the exploration and analysis of the logic schema;
- the second quarter of the period is more focused on producing a first draft of the electrical structure;
- the third quarter corresponds to a check of the intrinsic electrical viability of the graphic image just produced and an evaluation of the overall electrical structure (given what was produced earlier);;
- the fourth period is devoted to checking that the electrical structure conforms to the logical schema and that the logic schema fits with the state of work in progress.

We note that as the designer's work advances, more and more time is spent on checking the intrinsic viability of his/her production. This translates into much less exploring of the logic schema (third quarter). This is because the developed schema produced is more and more complex. As a result, checking its intrinsic viability is itself more complex and is done more through internal analysis than by comparison with the logic schema.

The designer's activity, underlain by the scheme, is not repeated in an entirely identical manner from one period to another. On the contrary, it adapts itself to the specifics of the situation, linked to both the contents of the logic schema and the evolution of the design situation resulting from the designer's activity and its results.

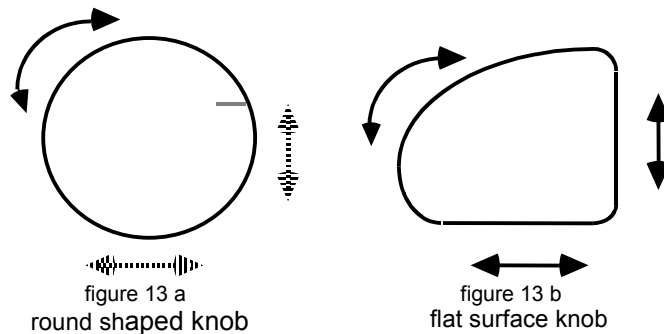
Utilization schemes

We will now define the notion of utilization schemes and the different types of schemes that make up the class of utilization schemes.

Let's take an example borrowed from Luigi Bandini Buti, a Milanese designer (in personal communication), concerning the use of a device designed to adjust a car seat. It is a knob placed on the side of the seat.:

There are three possible motions:

- rotation of the knob allows the user to control the reclining of the seat
- a horizontal translatory motion controls the distance from wheel to seat;
- a vertical translatory motion adjusts the height of the seat.



Two types of car seat adjustment knobs (Bandini Buti)

The first knob designed was round shaped. (fig.13 a). It systematically induced users to perform a rotation motion since translatory motions are very difficult to identify. The second knob consisted of two flat surfaces oriented horizontally and vertically, linked by a round shape (fig.13 b). This combination of shapes actually suggested the different possible motions and triggered, through tactile perception, the corresponding actions (turn, pull upwards, or push downwards...)

This example only deals with the mobilization of very elementary utilization schemes (turn, pull, push). These are basic constituents of a utilization scheme they are part of: the adjustment scheme. Indeed, during the subject's first encounters with the adjustment device, the relationship action-results (in terms of effects on the seat) is not yet fully constituted (this action brings about that result), even though it is constituted in principle (it is through action on the knob that adjustment can be achieved). The same goes for the sequencing of actions. The initial learning objective will be to constitute the adjustment scheme (or the coordinated set of schemes), which will then be associated with the artifact (the knob, site of the actions) to form an instrument allowing the subject to act on the object (the seat, site of the effects).

Schemes linked to the utilization of an artifact, which we call **utilization schemes (U. Sch)**, pertain to two dimensions of the activity:

- activities related to "secondary" tasks⁴⁴, i.e. related to the management of characteristics and properties specific to the artifact. In our example, the elementary utilization schemes for the handling of the control knob are located at this level;
- primary activities, or main activities, oriented towards the object of the activity, and for which the artifact is a means of performance. The adjustment scheme of the seat as a whole is located at this level. Coherence of the whole

⁴⁴ The meaning we give here to the notion of secondary task is very different from the meaning given to it in experimental psychology where it is seen as a disruptive task introduced so as to study the profound mechanisms of behavior relative to the main task. In situations of activities with instruments, the secondary tasks, while different from the main tasks, are functional and can in some cases include their own goals.

is insured, following Piaget's formula, by the global meaning of the action: adjusting the seat.

This leads us to define, in a first stage, two levels of schemes within utilization schemes:

- **usage schemes (Us. Sch)** related to “**secondary tasks**”. These can, as in our example, be located at the level of elementary schemes (meaning they cannot be broken down into smaller units liable to meet an identifiable sub-goal), but it is by no means necessary: they can themselves be constituted as wholes articulating a set of elementary schemes. Their distinctive feature is that they are orientated towards secondary tasks corresponding to the specific actions and activities directly related to the artifact;

- **instrument-mediated action schemes, (Im. A. Sch)** which consist of wholes deriving their meaning from the global action which aims at operating transformations on the object of activity. These schemes incorporate usage schemes as constituents. Their distinctive feature is their relation to “**primary tasks**”. They make up what Vygotsky called “instrumental acts”, which, due to the introduction of the instrument, involve a restructuring of the activity directed towards the subject's main goal. According to Cellérier's terminology (1979 a & b), usage schemes (Us. Sch) constitute specialized modules, which, in coordination with one another and also with other schemes, assimilate and mutually adapt in order to constitute instrument-mediated action schemes (Im. A. Sch).

Let's take an example. For an experienced driver, overtaking a vehicle is a type of action which comprises identifiable invariables: analysis of the situation to determine the appropriate moment, indication of his/her intention to overtake, change of gears if necessary, change in the vehicle's trajectory etc. An instrument-mediated action scheme underlies the invariable aspects of such an overtaking situation. This scheme incorporates as components usage schemes subordinate to its general organization, such as those necessary to manage a change of gears or a change of trajectory.

What emerges from the criteria we use to define schemes (their relationship to a main or secondary task) is that the nature of a usage scheme, or an instrument-mediated action scheme, does not refer to a property of the scheme in itself, but to its status within the subject's finalized activity. Thus, a same scheme may, depending on the situation, have the status of a usage scheme (for instance, changing gears in the overtaking example) or that of an instrument-mediated action scheme (for instance, for a beginner, where the question is learning how to change gears) ⁴⁵.

The analysis of schemes involved in instrument-mediated activities cannot be limited to a single individual subject. Indeed, instrumental usage is

⁴⁵ The relative nature of distinctions is very general in conceptualizations that refer to action. This is the case, for instance, of distinctions between action and operation in Leontiev's approach (1976) and between the strategic and tactical levels in fighting forest fires (Rogalski, personal message) in analyses in terms of goal, sub-goal, etc.

often located in the context of a collective activity, in particular in the workplace. A same artifact (or even a class of artifacts) can be used simultaneously or jointly by a group of workers to carry out a common or shared task.

While it is obvious that the subjects introduced in this collective activity implement utilization schemes corresponding to the various types referred to above, it is no less obvious that the collective nature of the activity, besides exceptions, calls for the constitution and implementation of specific schemes.

A third level of schemes must, therefore, be considered: that of **instrument-mediated collective activity schemes (Im. C. A. Sch.)**. These concern the specification of the types of action or activity, of the types of acceptable results etc. when the group shares a same instrument or works with a same class of instruments. They also concern the coordination of individual actions and integration of their results as a contribution to the achievement of common goals⁴⁶.

The different types of Im. C. A. Sch., Im. S. Sch and Us. Sch schemes make up the class of schemes that we call utilization schemes (U. Sch). We put forward the hypothesis that these different types of schemes are mutually dependent: based on usage schemes and instrument-mediated action schemes, collective instrument-mediated activity schemes can emerge, change form and become generalized. On the other hand, collective instrument-mediated are a source from which Im. S. Sch and Us. Sch type schemes can develop and change form, etc.

Finally, it should be stressed that utilization schemes have both private and social dimensions. The private dimension is specific to each individual. The social dimension comes from the fact that schemes develop in the course of a process in which the subject is not isolated. Other users, as well as artifact designers, contribute to this emergence of schemes.

Schemes are the object of more or less formalized transmissions and transfers: information passed on from one user to another; training structured around complex technical systems; various types of users' support (instruction manuals, users' guides and various other supports introduced or not in the artifact itself). This is why we have called U. Sch **Social utilization schemes (S. U. Sch)**. Thus, the social nature of schemes can by no means be confused with the fact that some of them are relative to instrument-mediated collective activities.

We will now look in greater detail at the shared characteristics of social utilization schemes.

⁴⁶ We will not develop any further the analysis of this schematic level, which remains fairly hypothetical, even if our initial results tend to confirm these hypotheses (Béguin 1994). We merely stress that, as for individual schemes, we should probably favor a hypothesis of schemes oriented toward secondary tasks and toward main tasks. The former are integratable and integrated modules in the more general wholes formed by the latter.

Utilization schemes are multi-functional in that they carry out:

- **epistemic functions** focused on understanding situations;
- **pragmatic functions** focused on transforming the situation and obtaining results;
- **heuristic functions** that orient and control the activity⁴⁷.

As with any scheme, they constitute frames that assimilate situations the subject is confronted with. They make it possible to assign meanings to objects according to the orientation of the subject's activity and tasks. They also make it possible to assign them a status both in terms of goals and sub-goals, of states, changes of states and transformations that can be operated on objects, and in terms of means, i.e. of instruments relevant to possible actions.

Utilization schemes are linked to artifacts that are liable to have the status of means as well as to the objects these artifacts make it possible to act on. They are organizers of the action, utilization, implementation and usage of the artifact. They take into account and rely on the properties of the artifact, which are themselves organizers⁴⁸.

However, utilization schemes cannot be applied directly. They must be adapted to the specificity of each situation. They are implemented in the form of a procedure relevant to the particularities of the situation.

These particularities can be limited to classes of familiar situations where the artifacts associated with the utilization schemes as well as the objects and their transformations are well known and identified by the subject. Operating invariables are constituted, at least in part, by a structured set of variables which are characteristic of the class of situations. The assimilation process leads to establishing the particular value of the variables according to the characteristics specific to the situation. Utilization schemes can then be considered as easy to mobilize, familiar schemes that contribute to the "automated" functioning that typifies well-mastered, common situations.

The implementation of utilization schemes in new but similar situations (assimilation process) leads to the generalization of schemes by extension of the classes of situations, of artifacts and objects they are relevant to. It also leads to their differentiation since most often they have to change to adapt to new and different aspects specific to situations.

⁴⁷ Let us stress that the heuristic function is not only due to the scheme but can also be carried by the artifact. It is thus the instrument as a whole that can participate in the subject's management of him/herself. We therefore follow Béguin (1994) in considering that it is a question of a true heuristic mediation.

⁴⁸ If an artifact is an activity organizer, it is of course in a different mode to that of schemes. We will analyze the characteristics in the following chapter in putting forward concepts of required activity and expansion of the range of possibilities.

In situations very new to the subject⁴⁹, the adaptation process becomes temporarily predominant. It leads to the transformation of available schemes, to their reorganization, fragmentation and restructuring, reciprocal assimilation and coordination, which progressively produces new scheme compositions allowing renewed and reproducible mastery of the new class of situations and beyond this to extended assimilation and adaptation potentialities. Such mechanisms emerge, for instance, when new artifacts must be used as means of action or when the action focuses on new objects or new transformations of these objects.

The assimilation of new objects and new artifacts in utilization schemes, source of both generalization and adaptational differentiation, leads to the enrichment and development of the subject's network of meanings, within which artifacts, objects and utilization schemes, are closely associated.

A psychological definition of the notion of instrument

We now have the necessary foundations to propose a psychological definition of the instrument. The essential point of this definition is that the instrument cannot be reduced to the artifact, the technical object or the machine, depending on the terminology employed. We propose defining the instrument as a mixed entity, born of both the subject and object (in the philosophical sense of the term): the instrument is a composite entity made up of an artifact component (an artifact, a fraction of an artifact or a set of artifacts) and a scheme component (one or more utilization schemes, often linked to more general action schemes). An instrument therefore consists of two types of entities:

- a material or symbolic artifact produced by the subject or others;
- one or more associated utilization schemes, resulting from an autonomous construction specific to the subject, or from an appropriation of S. U. Sch. already formed outside of him/her

We are, therefore, led to extend Mounoud's definition (1970) according to which an instrument can be any object the subject associates with his/her action to perform a task. It is not only the "object" associated, and associable, by the subject with his/her action for the performance of the task, it is also the utilization schemes that will allow the introduction of an instrument as a functional component of the subject's action. It should be noted that Monoud calls object what we call artifact.

This means that the constitution of the instrumental entity is the product of the subject's activity. The instrument is not only part of the subject's external world or something available to be associated with an action (or even necessarily associated, as is often the case in the workplace). It is also the subject's production or construction. This is obvious as far as utilization

⁴⁹ This is often true of situations which numerous authors (Norman 1988, Bodker 1989a, etc.) call "breakdown situations". These are situations where automated functioning, for various reasons, can no longer occur and where the subject consciously takes over.

schemes go but in the following chapter, we will see that similar processes also exist for the artifact part.

This definition of the instrument allows us to overcome the seeming contradiction that may arise between approaches which grant the status of instrument exclusively to objects external to the subject (artifacts), or restrict the status of instrument to the subject's schemes. Both these symmetrical options lead to almost completely negating one of the two components of the instrumental entity.

The two components of the instrument, artifact and scheme, are associated with each other, but they also have a relationship of relative independence. A same utilization scheme can be applied to a range of artifacts belonging to the same class (such as car driving schemes transposed by the subject from one car to another) and also be relevant to similar or different classes (often not without problems, as we have seen in the case of microwave ovens). Conversely, an artifact is liable to be integrated into a range of utilization schemes, which will sometimes assign it different meanings and functions. We all have examples in mind such as the association of the scheme "strike" with a wrench, turning it into an instrument with the same function as a hammer, or even a blunt instrument.

The constituted instrument can be ephemeral, linked only to the particular circumstances and conditions of a situation the subject is confronted with, but it can also be of a more permanent nature and be retained as a whole as a means available for future actions. This dynamic whole will, of course, develop in line with other action situations in which the subject will involve the instrument. Thus the instrument as a whole, as well as each of its components, is a form of capitalized experience, or knowledge. This is one of the main characteristics defined in the literature.

But how can the instrument thus defined occupy an intermediary, mediating position between the subject and object, since, as both scheme and artifact, it pertains to both? The answer to this question is to be sought in the relation of the instrument to the action. The subject institutes certain components of his/her environment as instruments according to his/her goal, i.e. as means for his/her action.

Just as these means can be part of his/her organism, for instance limbs or sensory organs, they can also be schemes. That is why Bullinger (1987 a & b) emphasizes that we must by no means confuse the subject and the functioning of the organism, since this would amount to concealing the origins of the instrumental activity. We know that the distinction between subject and functioning has a status in the subject's very activity. An example of this is in the abstraction process (empirical and reflective) in which the subject takes his/her own schemes as object. Thus in the finalized activity, utilization schemes are not only in an external (instrumental) position. They can also be in the position of object, particularly when the orientation of the finalized activity is epistemic.

Likewise, the instrumental position of the artifact is relative to its status within the action. The artifact is not an instrument or an instrument component

in itself (even when it was initially designed as such); it is instituted as an instrument by the subject who gives it the status of means to achieve the goals of his/her action. In this respect, artifacts integrate the activity and bring about more or less significant reorganizations. Thus, a same artifact can have very different instrumental statuses depending on the subjects and for a same subject, depending on the situation and even different moments of this situation.

For subjects, an artifact is enriched by the action situations it has been circumstantially involved in, specifically, as a means of their action. This is how what we could call the palette, the instrumental field of the artifact comes into being for the subject: the set of artifact utilization schemes it can be introduced into in order to form an instrument; the set of objects it allows the subject to act on; the set of transformations and changes of states it allows the subject to perform. Artifact utilization schemes become richer and more varied with the evolution of the artifact's instrumental field. They evolve with the range of artifacts they are associated with to form an instrument and with the range of statuses they may take on within this association.

In such a frame of thought, the permanence of utilization schemes, specifying one or more artifacts with defined properties, allows us to define one of the dimensions of instrument preservation for the subject. Indeed, there is no instrument without artifact. Nonetheless, the preservation of the artifact component can concern a class of objects (and not a specific artifact) when the subject in his/her action environment has permanent access to elements or artifacts with the properties necessary for it to be associated with utilization schemes in order to form the instrument required by the action in progress⁵⁰. The function in terms of possible changes in state can thus be disassociated from the artifact and associated with the subject. Function in action is a characteristic of the subject, not the artifact.

A permanent instrument, liable to be preserved and thus reused, is made up of the stabilized association of two invariants (which can be classes of invariants). Together, they constitute a potential means of solving, dealing with and acting in a situation. However, the question of the constitution or genesis of the permanent instrument is thrown up: how are its two schematic and artifactual invariants constituted? Whether it concerns the scheme or the artifact, this construction generally does not occur in a vacuum. The artifacts are most often pre-existing but are nonetheless instrumentalized by the subject. Schemes most often spring from the subject's repertory and are extended or adapted to the new artifact. Sometimes, entirely new schemes must be constructed: these processes as a whole can be described as instrumentation and instrumentalization processes.

⁵⁰ We will return briefly to the animal world. Recent observations (Boesch & Boesch-Achermann 1991) revealed that a monkey extracting termites often used three types of sticks with well-differentiated functions. The artifactual component of these instruments is not preserved. Monkeys can find plenty of them in their environment. However, repetitive and similar usage of artifacts with differentiated properties can be interpreted as a sign of their insertion in permanent utilization schemes that thus preserve the instruments.

In the third section, we will look at questions concerning instrumental genesis and processes of instrumentation and instrumentalization.

