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M. R. A. Chance

Towards the Derivation of a Scientific Basis for Ethics

A Scientific Ethic out of the Logic of the Two Socio-Mental Modes (Agonic and Hedonic)

Abstract

Ethological examples are given which show how social attention can be assessed. Classification of the social structure of old world monkey species (Cercopithecoidea) on the basis of the predominant attention that individuals pay to social companions or the physical environment reveals that they can be divided into acentric (environmentally oriented) on centric (socially oriented) the latter being rank ordered around a central dominant individual, usually a male. They are, when active, tense spatially separated into sub-groups, and rank ordered, showing dominance and submission. These are agonic types based on self protective social relations.
Contrasting with these are the species of the Hominiodea, with the exception of the gibbons (Hylobatidae) i.e., the chimpanzees, the gorilla and the Orang-Utan, they are relaxed and languid in their movements and, with the exception of wild Orangs, make frequent body contact often in the form of reassurance and greeting gestures. They are exploratory and inventive. These are the hedonic species.
Human agonic personalities give rise to dictatorship. These will always arise in modern societies and their influence can be counteracted only be being aware of their characteristics. So that progressive authority can be maintained despite the influence of agonic personalities ethical principles which can guide progressive actions, are deduced and defined.

Key words

Socio-mental bimodality, agonic, hedonic, ethology, psychology, anthropology, sociology, scientific ethic.

Until now the intellectual basis of ethics has been propounded and in some sense evolved from the sequential insights of philosophers down the ages (Magee 1987). This has led to conflict in argument and the absence of a logical progression of thought. With the knowledge that we are the product of evolution, it is now clear that we can no longer rely for the intellectual justification of ethics on an *ad hoc* set of propositions, but must seek the foundation for a lasting (if evolving) system of ethics in evolutionary biology and specifically in the etho–psychological investigation of our thought processes.

The possibility of the scientific ethic arises out of the way we interpret current events when our thought is based in an understanding of the two modes because the two inherent socio-mental modes (agonic and hedonic) are at one and the same time a property of our minds and of the corresponding social relations; either one engendering the other.

Now let me explain how I came to this understanding, and for that let us start by reminding ourselves of the enduring image, which as ethologists we all remember, of Konrad Lorenz swimming in a lake surrounded by a lot of little goslings.

Psychology at the time Lorenz started his observation of natural behavior, was concerned with learning theory, so it was that by observing the hatching of the young goslings he discovered imprinting.

Prompted by my experience of politics I became concerned with social structure as I saw in this same image of Lorenz surrounded by goslings the fact that they were constantly paying attention to him. That, if you like, their predominant attention was directed at him, and that as with a mother goose they followed him everywhere he went.

Let me now convince you that predominant attention can be assessed in other situations involving mammals.

Figure 1 shows the flight pathways of the subordinate rat in an encounter between the home owner and the intruder. There are essentially two forms of

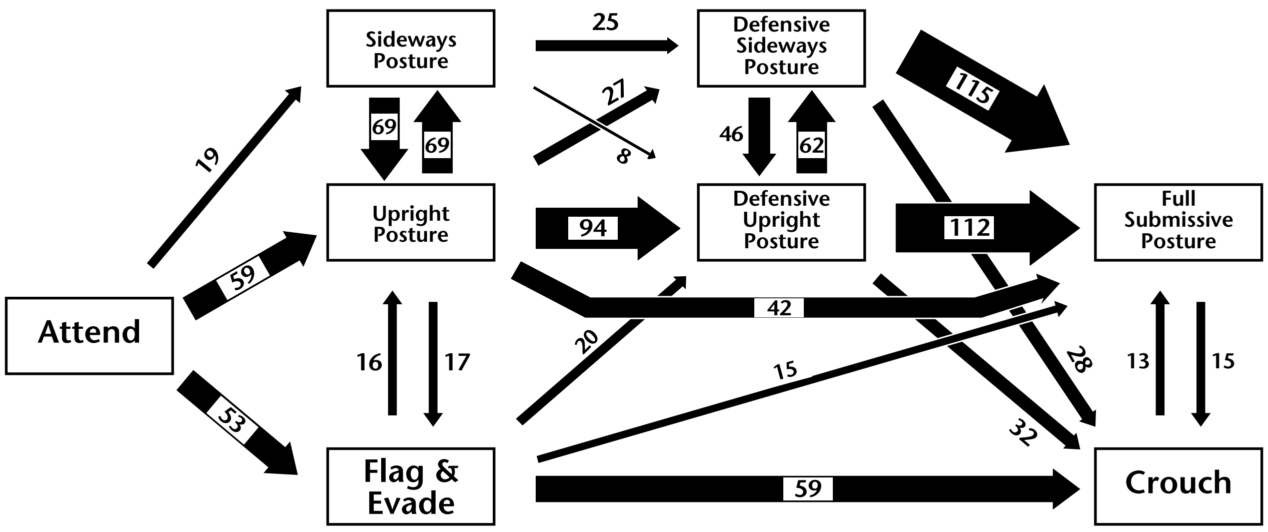

Figure 1: Diagram of the flight pathways recorded during encounters between two rats. The diagram demonstrates an escape pathway leading from Attend through Flag and Evade, to *Crouch* (blocked escape), and a social submission pathway leading from Attend through alternating Sideways and Upright postures to Full Submission. The numbers indicate the relative frequency with which each pathway is used. (*See* GRANT 1963).

escape. One in which the subordinate rat crouches in which event the home rat continues to nudge nibble at the crouching rat and another one in which the rat has submitted by lying on its back when the home rat immediately turns away and starts self grooming, moving round the cage, eating etc. showing clearly that the home rats attention has turned away from the intruder (GRANT 1963).

If a rat is placed in a room 8ft square with sawdust and peat spread on the floor so that it can be observed living there for some time, it soon begins digging under light switches on the wall showing that its attention is directed upwards at objects well above it, which was totally unexpected.

Now look at the way different species of monkey behave in the wild (CHANCE/JOLLY (1970) Figs. 2, 3 and 4). Figure 2 shows how the individuals in a troop (The Patas monkey) are spaced out. Look first at the *centre strip* which shows the troop feeding with the single male separated from the females and young and close to a prominent feature of the environment (a bush or rock), on which he will display when a predator approaches while the females and young crouch in the undergrowth *lower strip*. Finally look at the top strip which shows them sleeping dispersed in the trees with the male in a separate tree. These monkeys are clearly environment orientated with their predominant attention on the environment.

Figure 3 shows how the troops of the langur behave in the same circumstances. When a predator appears they all escape to the safety of the trees, but then clump together when sleeping showing firstly an acentric and then a centric form of predominant attention.

Lastly, in Figure 4 the behavior of the Savannah Baboon shows a form of predominant attention creating a centric form of social organization in which the predominant attention is always on the dominant male.

When I observed a colony of Rhesus Macacs (CHANCE 1956) in the London Zoo in 1953, and made a film of them, it was clear that although the dominant male monkey was the most relaxed in the colony, when he took action it was sudden, jerky and deliberate and that all other adults, 2 males and some 10 females, were most of the time tense in the posture they adopted. Repeatedly looking at when they were in the presence of the dominant male, oriented or repeatedly glancing at him. On patrol, he walked with a stiff displaying gait with tail raised when all the monkeys moved out of the way. These features were also observed in a small semi-feral group in the Dudley Zoo, West Midlands.

VIRGO/WATERHOUSE (1969) studied a semi-feral colony of Rhesus Macacs at the Bristol Zoo in 1967, and found from observations at the feeding site that there were two animals who had priority of access to food, one an unaggressive large male who was groomed and frequently displayed, the other one a highly aggressive female who was not often groomed and did not display, and they concluded that any theory of social attention must take into account "the possibility of divided foci of attention".

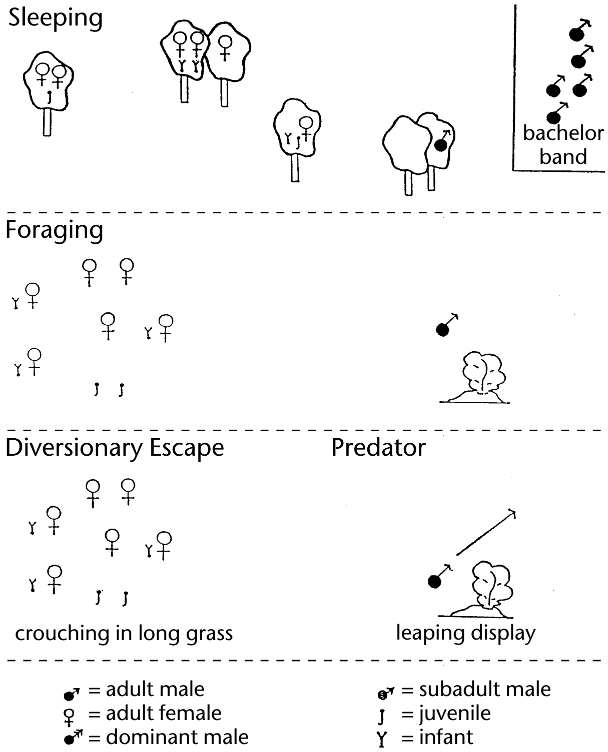

Figure 2: Patterns of aggregation and dispersal in an acentric society—patas monkey, *Erythrocctus patas*.

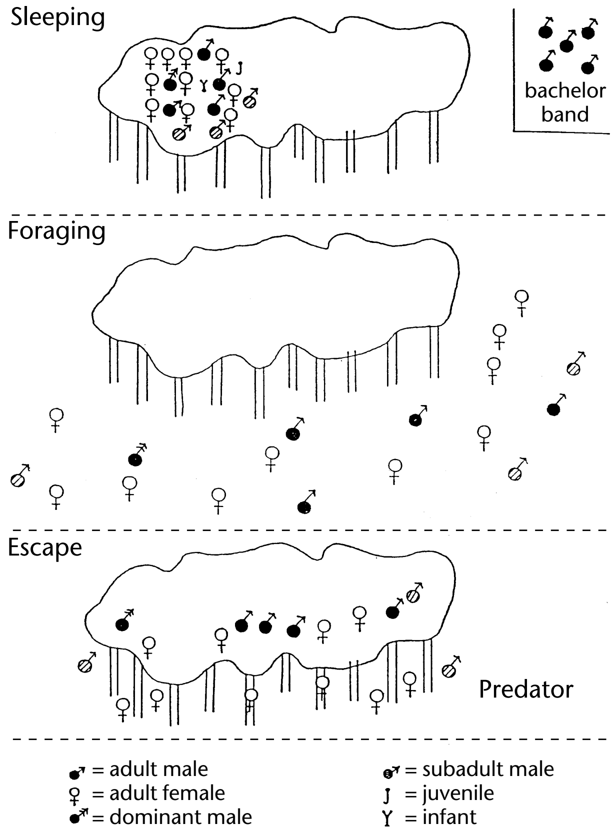

Figure 3: Patterns of aggregation and dispersal in a society showing both acentric and centripetal tendencies—langurs, *Presbytes entellus*.

Now that the WATERHOUSE's have shown that the agonic (controlled by threat) and hedonic (controlled by display) focusing behavior is present in the rhesus macaque, though acted out by different individuals in the group, and Pitcairn has found a dichotomy of gaze behavior which parallels this distinction in another species of macaque, it is clear that the individuals of a single species do possess the behavioral attributes of both agonistic and hedonic ways of behaving socially. We have, therefore, by describing these societies, identified two distinct modalities of social behavior. These are the agonic and hedonic modes.

Agonic Mode

Members of agonic groups travel together and function in stable troop formations. Those who attain and maintain dominance in agonic groups do so through acts of agonistic display and less frequently overt acts of aggression (e.g., staring, neck biting, and other acts of intimidation). At the slightest provocation, less dominant members are ready to perform acts of submission or appeasement to ward off attack. Submissive members of these troops never stray very far from the dominants to ensure they have a full view of their actions, but maintain a respectful distance to keep out of "harms way". Threats from dominants (both explicit and implicit) keep members of the troop spatially separated but clustered closely in a single formation. Because of the ever present possibility of aggressive attack from within, most animals in agonic groups are in a constant state of high arousal. Except for those whose role it is to scan the environment for potential predatory threats, most of the troop keep their attention focused on the dominants. As a result, they show little curiosity about others in the group or their physical surroundings. In the agonic mode, the group's social attention is focused almost exclusively on its dominant members. When external danger threatens, the troop clusters together and looks to the dominant for protection and direction.

Hedonic Mode

Members of hedonic groups exhibit behavior which is more variable and flexible. Unlike agonic troops, members of hedonic groups do not need to be in

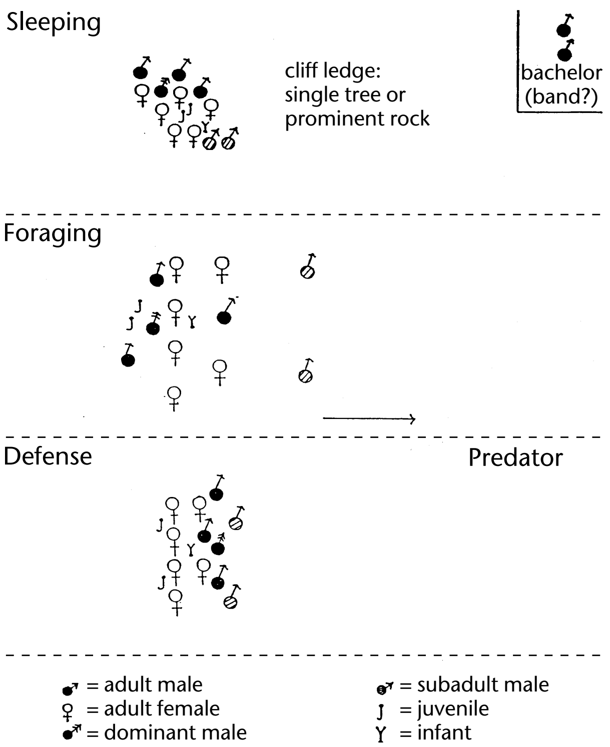

Figure 4: Patterns of aggregation and dispersal in a centripetal society—savannah baboons, *Papio cynocephalus*.

constant view of each other. They easily split off in small foraging groups with shifting composition in a pattern of periodic separation and cohesion referred to as fission/fusion. When separated members return to the main group the atmosphere is very social and interactive. The mood is so festive and positive that REYNOLDS (1965) has compared it to that of a "carnival".

Individuals relate to one another without reference to the dominance hierarchy. They interact actively with their environment, handling objects with interest and curiosity. Prominence, not dominance, is sought through various forms of display behavior. Rank is determined by a process of social solicitation not intimidation. Individuals "compete" for the attention of others through display behaviors. These are frequently followed by interpersonal rewards such as grooming, play and mothering behavior or by communal activities such as food sharing. There is little outward conflict within the group. Because members of the group are not in a constant state of anxiety the arousal of the individual members fluctuates.

When danger threatens the hedonic group, it responds in a completely different manner to that of agonic troops. It gathers: "together as a group, making body contact, slapping and hugging each other, from which activity each member gathers confidence to attach the predator on its own. The group is not the source of common defense as in the agonic mode, but a source of mutual confidence from which the individual makes individual assaults".

In the agonic mode individuals are in a rigid relation to one another through the binding of their attention onto a single social focus. As long as this occurs the attention of the individual is not free to be organized in any other way. The implications of the WATERHOUSE's findings, combined with those of Pitcairn, shows us that in these cercopithecoid species social cohesion is achieved by an oscillation between the cohesion achieved by agonistic attention focusing alternating with hedonic display focusing of social attention, and that the changeover takes place in a short space of time. What, therefore, we must ask, would be the consequences of liberating the attentional system from the preoccupation with social cohesion? The answer is that it becomes capable of organizing the individual's awareness of the properties of things in creatures whose faculties of exploration and investigation can then become compounded into curiosity. This implies an attentional span of sufficient duration to enable manipulation and investigation to lead to discovery. KÖHLER (1927) equated this with intelligence in the form it takes in problem solving, but, as MENZEL has shown, chimpanzees will find their own problems to solve and thus become truly inventive, given conditions of minimum concern with social cohesion.

My first and most rewarding encounter with chimpanzees was with those kept by William MENZEL at Covington, Louisiana, while I was staying with Hans KUMMER. This semi-feral group was kept in an oval enclosure of a pine forest with undergrowth between the trees about 200 yards long by 100 yards wide. There were 7 adult males whose foraging behavior was being studied, but what was immediately obvious was the languid movements interspersed with frequent touching, hugging, kissing etc. While they could be very vigorous and rapid, this was worked up to by the movements gradually becoming faster.

Very soon, they stripped some of the branches off the trees and cleared them of side branches and then used them as poles for pole-vaulting which they initially used to lay against the trees and overcome the electrified barbed wire which was put round the trees to prevent them climbing up. Then they transferred this procedure to look into an observation cubicle and finally to get out of the enclosure over the top of the 15ft high wire fence. Here we see a flexibility of attention and arousal.

The outstanding feature, which is apparent to any observer, is the flexibility of the chimpanzee's behavior. Analysis of the structure of the repertoire shows that the transitional probabilities between acts do not show strong linkages and are not grouped into the simple motivational categories of, say, the rhesus or long-tailed macaques. Together with this goes a great variability of attentional styles. How does the latter come about? Mainly, I think, because the quiet state of the individual is due to much body contact bringing about relaxation and then excitement arises in response to specific situations. Yet this excitement is still under control owing to the social excitement being kept down by the constant interspersing of most activities with body contact. This specifically creates for the first time the modulation of arousal by interest leading to curiosity and the integration of much information about physical objects and their manipulable potential, which as MENZEL (1972) has shown leads to inventiveness. This is itself dependent upon a flexibility of attention that enables the individuals to pay attention to all aspects of an object, i.e., awareness of its properties in relation to the physical environment as well as in relation to the animal's manipulation of it. However, in the background of all this is the persistent control of social arousal which does not interfere with the arousal of interest.

What I have been suggesting is that under the anthropoid label, two distinct modalities of operation exist which are, by their nature, mutually exclusive because one imposes rigid conformity with in-built social strategies and hence imposes a preordained selectivity on awareness, while the other operates when social relations are flexible and opens up awareness to the operation of intelligence.

This attention to environmental elements has led different groups of chimpanzees in Africa to develop skills creating different technical cultures, many using sticks cleared of side branches to feed on ants—at least one other to crack open nuts with a stone axe on a stone anvil (MCGREW 1993).

BOLWIG (1963) kept a tame infant baboon as a pet in the family when they lived in Africa and just before it became an adult he tested it in the way KÖHLER tested the intelligence of his chimpanzees when he was on the island of Tenerife. He found that they performed about as well, which indicates that, allowed to grow up without constant preoccupation with its social status, its mind was as flexible as a chimpanzees! LACEY (1963) has shown that humans take in information when the heart rate is slowing, but reject it in favor of internal processing of information (or reflection) when the heart rate increases—demonstrating how oscillating arousal is the basis of inquisitive interest; the basis of creativity and intelligence.

The Human Scene[1]

The Agonic Social Mode

It is often remarked that where there is a "bad atmosphere" in a department of an organization, there is always present an authoritarian person, usually in authority, who will be over-controlling the group by intimidation varying in intensity from barely perceptible insinuation to periodic outright abuse. "Subordinated" individuals are often unconscious of their reaction and find themselves unable to resist because they are unaware of the source of their emotional disturbance.

In a less marked manner, in such situations, we become primarily concerned with self-security and our attention is much taken up with being part of a group and with what others think of us so as to assure acceptance by the group. We become concerned about rank hierarchy, convention and maintaining good order. In this mode our concerns are predominantly self-protective and our minds engage information-processing systems in our brains that are specifically designed to attend, recognize and respond to potential threats to ourselves, our status and social presentation.

The Hedonic Social Mode

The hedonic mode is marked by the absence of agonic features: since members of a group may not have experienced anything else they do not necessarily know that they are in the hedonic mode. In the hedonic mode people come together in order to enjoy each other's company as such, or to enjoy some common activity or undertake a specific task. There will be a free flow of information between the members, one aspect of which is consultation by leaders with operatives (often with an interchange of roles). This prevents the handing out of excessively detailed instructions (over control). Individuals are valued or esteemed for their qualities rather than being classified by signs of rank.

Being valued reinforces the individual's sense of social security. This underpins a freedom of association which creates a social network rather than a hierarchy of social rank. As a result the hedonic human being has a flexibility of arousal and attention that allows time for the integration of reality, interpersonal relations, private feelings and thoughts—prerequisites for the operation of intelligence.

The rise of dictatorships has been a feature of the world scene throughout my life and is clearly a deep seated tendency in our nature. Dictators represent the agonic mode extrapolated by modern industrial society which is then reflected back onto societies in parts of the world where tribalism is emerging into conscious awareness of the industrialized world itself. Dictators then represent the embodiment of the agonic mode in the modern world. They emerge by display combined with intimidatory (aggressive) self defensive behavior which enables them to surround themselves by a bodyguard of devoted, often disaffected, followers (STAUB 1989) The predominant attention of the followers is bound to them by just the same inherited brain mechanism which we have seen operating in agonic monkey groups.

Take HITLER as an example. He early on built a small group which was the forerunner of the Nazi Party. It is most important to note that at the beginning he had no policy other than to build up what he called the "defence industry", and the roads to make, what was in effect, the army, mobile. It appears that both the creation of the Bierkeller group in Munich and the sole specification of policy in the form of a so called defence industry, represented his deep seated self defensive state of mind, designed both out of this state of mind and his inability to think out a policy. The final items of his racial policy, army, navy and airforce policies accreted around him as these elements of the final policy were put forward by acolytes who set out to curry favor with him by suggesting what they thought would please him and so enhance their status in his eyes.

Another instructive example is that of Idi AMIN who became dictator of Uganda after attending Sandhurst Military College for the British Army, and who had been recruited by a junior Foreign Office official.

He is seen addressing his supporters after becoming dictator. He emphasizes loyalty, but stresses that it is important that his followers should show him love and affection as a way of supporting his rule. It is almost pathetic how he almost pleads for this attitude. We can see how a person taken out of a tribal background is transported to a wholly alien European environment who succeeds by obeying all the rules of the military college, then finds himself back in his old country devoid of any policy (which he might have acquired at a University). Thrown back on his wits and in the new frightening circumstances he draws instinctively on his inherited instruction resources of his self protective mind to guide him to personal safety, rather than to construct a policy for his country, for which in any event there was no precedent!

Other dictators are Jose MARCOS of the Philippines and M'BUTO of Zaire. All were got rid of by revolution, or in HITLER's case, defeat in war.

At this point we need to distinguish between Authority and Authoritarian (dictatorial) behavior. Authoritative behavior involves taking responsibility for a community's affairs in contrast to what we have seen in the behavior of dictators; self defensive concern placing that individual in a safe position within the community, either by over-controlling it from a position of high status, or by becoming over servile and too ready to follow the dictates of recently usurped authority. As we have seen in both the rise of HITLER and the assumption of rule in Uganda by Idi AMIN, both lacked a clear policy, and could have been successfully challenged and prevented from gaining power, if a politician with a worked out policy had been on the scene. This is the modern embodiment of the phase "eternal vigilance is the price of freedom", and should be easier to achieve in future as the world-wide dissemination of information grows.

An alternative is a symbolic head of state, alert to the possible function they may be called upon to perform to defend freedom, such as was so ably performed by King CARLOS of Spain in his assumption of office on the death of General FRANCO. By taking on the position of hereditary ruler he was able to nurture the rise of democracy in a country consisting of several ethnic groups, 40% of which do not speak Spanish. This amounted to the creation of an authoritative enclave promoting hedonic freedom.

Business, Industry and Manufacture

Several works have appeared over the last 10–15 years which make it clear that new (hedonic) forms of administration have begun to replace the earlier (agonic) forms of hierarchical control inherited from the last century. Of great significance is the realization that industries have growth cycles like other organic individuals which are born, grow and decline into old age and death. In this instance, industries go out of business. Prominent amongst these is "The Change Masters" by KANTER (1983).

She distinguishes between "segmentalist" older type companies which have a compartmental outlook, are rigid and resist change, and a new type which is capable of integrating its parts by changing to a corporate type organization in which individuals at all levels can contribute new ideas so that the organization is thereby revived from within. Examples of this type of change demonstrate that when social and organizational environments are hospitable, people's natural inventiveness and power skills can make almost anything happen.

It has long been known that NASA, the National Space Administration of the U.S.A., has had to rely for its success on encouraging the maximum self reliance and intelligence in the personnel, not only of the crew of the space craft themselves, but in the administration as a whole. Where compartmentalization was necessary for reasons of secrecy in the Manhattan Project (which developed the atomic bomb), maximum freedom of association within each unit had to be guaranteed to achieve success.

Alvin TOFFLER (1990) pointed out that technical changes bringing about the wider dissemination of knowledge have also made information of all kinds more accessible, finally leading to the internet.

Agonic personality types, because of their acquired insecurity, will always be around imposing over-control or remaining gripped by obsequious submissiveness. So we must realize that we need to make determined efforts to create secure enclaves within industrial environments to bring about change. The way this has been achieved very successfully is described by Ricardo SEMLER (1994). Here he describes the inception and history of the Brazilian firm SEMCO in Sao Paulo, manufacturing "pumps that can empty an oil tanker in a night, dishwashers capable of scrubbing 4,100 plates an hour, office block air conditioners" etc.

Antonio Curt SEMLER was born in Vienna in 1912, went abroad and visited Brazil in 1952, and Semco was started: Ricardo took over from his traditionalist father in 1982, and from then on Semco was transformed. "It was a traditional company in every respect with a pyramidal structure and rule for every contingency. But today our workers sometimes set their own production quotas and even arrange, in their own time, to meet these quotas without prodding from management." The workers all care about their jobs as well as the company, and because advancement is judged by gatherings of the workforce on competence and not on longevity or conformity, the trade union membership is ready to allow innovation, with the result that each manufacturing unit has been able to reduce its legal aid requirements, its accounting and reliance on marketing advice, by 75%, during which time the company has grown six times in size.

Put briefly, the success is due to the generation of absolute trust between individuals and self governing groups. Not unexpectedly from our evolutionary perspective, the behavior of individuals improved at home as their participation with others of the workforce gave them experience of trust, so the individual relaxed. "No longer does my husband yell at the children, but asks everyone what they want to do on weekends" one of the wives exclaimed!

Another, though less radical approach to reconstructing social relations within industry and which takes into account the personalities of participants is in consciously putting together contrasting types to construct Management teams (BELBIN 1981) An Industrial Research Unit from Cambridge that was part located at the Administrative Staff College in Henley, started from the belief that "the concentration of power tends to corrupt, so it is best to share power". Being constructivists they did not enquire how this tendency repeatedly arose which ethologists see as corruption of the intent of management by the insidious influence of our evolutionary inheritance. Rather, they saw it as inherited from the authoritarian influences of the 19th Century. The movement away from the "Boss" in charge to team work, they noted, was taking place, but recognized that little research had been done into the effectiveness of team work.

This approach clearly set out to spread the decision making process out of the hands of a single individual and into the corporate decision of several individuals, but by retaining the role of chairman the structure which was being planned was clearly hierarchical and liable, in the event, to repeated failures.

In designing a team they saw "personal qualities as fitting members for some team roles, while limiting the likelihood that they would succeed in others". In adopting this approach, they had no conception of a developing system in which the personalities participating would grow with the growth of the system as a whole. This can be said of earlier examples where individuals creativity has been given free reign, as with NASA or the Manhattan Project, which have been constructed with lit-

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tle reference to the society from which they have sprung, unlike the influence of Diana, Princess of Wales, who we can now see has transformed the social consciousness world-wide, and altered forever the structure of English Society.

These examples demonstrate that whenever and wherever hedonic social organization can promote a cause it can, and often does, succeed in doing so.

Nevertheless, agonic types will always be around having grown up programmed by their early childhood experiences to take over control wherever an opportunity can be seized. So long as the economy remains stable the likelihood of dictatorships arising on the national scale is minimized, but local attempts to gain control of specific organizations will always be encountered, and can only be prevented if detected early. This is why an understanding of the two modes is essential for improvements in society. If this is so, then this is an ethical injunction and the first time it has been possible to base an ethical judgement upon a scientific basis. It is the first time we can link ethics to science. This is because ethology has led us to study the relevant aspects of scientific discovery.

This scientific ethic, and there may be others to be found, alerts us to the need to resist agonic take-overs in the one hand, and on the other to create hedonic enclaves as a means of promoting progressive causes.

Conclusion: A Scientific Ethic out of the Logic of the Two Socio–Mental Modes (Agonic and Hedonic)

An ethic based on knowledge gained through scientific investigation has been discovered and arises out of the nature of the two socio–mental modes (agonic and hedonic).

It is now possible to understand what we mean by the phase *"eternal vigilance is the price of freedom"*. Agonic personality types may be thrust into or become dropped into positions where they are expected to wield authority without possessing any view of what authority is about, i.e., pursuing a policy beneficial to the community. A defective awareness is evident in the absence of a policy, but also most significantly in the readiness with which aims are compromised or dropped in favor of tactics which enhance personal control; (LENIN was an example). They are in reality very vulnerable, and can be easily challenged at this stage, provided the challenge is made early and with conviction.

Realization of this is the first ethic, the second is to act on it and challenge them.

When a progressive person, backed up by his supporters is in a position of authority, his function is to create an hedonic enclave for the pursuit of the progressive social aims of his group. This is the third ethic.

Appendix 1

Psychiatry	
G. VAILLANT (1977)	Adaption to Life (Little Brown & Co., Boston, USA)
J. PIERCE/ S. NEWTON (1969)	Conditions of Human Growth (Citadel Press N.Y.)
Sociology	
L. D. CARTER (1954)	Evaluating the Performance of Individuals as Members of Small Groups (Personal Psychology 7: 477–484)
R. COLLINS (1981)	On the Microfoundations of Macrosociology (A.M.J. Sociol 86: 984–1014)
T. D. KEMPER (1978)	A Social Interactional Theory of Emotion (J. Wiley, New York, Chichester)
Social Behaviour of Children	
H. MONTAGNER (1988) C. BARNER BARRY (1988) V. REYNOLDS (1988)	Social Fabrics of the Mind (L.E.A. Hove, U.K. / Hillsdale, U.S.A)
Hunter Gatherers	
See Social Fabrics of the Mind.	
Further Reading	
M. R. A. CHANCE	A Socio–mental Bimodality. Chapter 16 in The Archaeology of Human Ancestry, ed. J. Steele J. and S. Shennan (Routledge, London and N.Y.)

Appendix 2

While this manuscript was being prepared for publication Prof. Izaak FREED came on the "Science" program of the B.B.C World Service (20.12.97) to claim he had discovered a new "medical" syndrome which he termed Syndrome E. to explain the Ruandan genocide. Comparing his explanation with that which is based on a evolutionary understanding of the structure and function of groups in an illuminating epistemological exercise. In his own words this was an excessive compulsive disorder in which emotional flatness is combined with fixed perseverating behavior cut off from the family life of the individual (compartmentalization) and which is dependent on the existence of a group which helps infect the individual through groups contagion. (the individuals are therefore different from serial killers who are loners).

The psychiatric nature of the mode of thought is clear and in the absence of any anthropological or ethological contribution is anything but scientific. That properly functioning groups have a structure which defines the social roles of individuals is not understood and the element of excessive overcontrol and perseveration are not seen for what they are originating in the agonic mode, these features being seen as "obsessional".

In attempting to interpret the underlying brain function he seems unaware of the hierarchical relationship of the higher neocortical structure to the other two lower brains based on the inhibition of the two lower by the higher but may be right in ascribing the mental state to a hyper arousal of the neocortex. In which event there has been an excess of excitement with a diminution of the inhibitory functions and a consequent lack of the cortical discriminatory ability, whatever the relation to lower centers eventually turns out to be.

What is brought into sharp relief by Prof. FREED's attempt to explain genocide is the "one off" nature of the explanation rather than one based on an awareness of evolutionary origins explicated by the bimodel socio–mental explanation.

Acknowledgments

I offer my thanks to Barbara DECKER PIERSE and Roderick WHITE of Richard Ivy School of Business, University of Western Ontario for permission to quote the consultation paper in press entitled "From Monkeys to Managers—a Socioevolutionary Line between Resource, Context and Social Structure".

Note

1 See Appendix 1 for further evidence.

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Lean Evolutionary Epistemology

Abstract

Euphoric claims about a "new evolutionary enlightenment" notwithstanding, EE seems to be reaching a stage of diminishing intellectual returns if conceived of narrowly as the systematic elaboration of the programmatic ideas of the founding fathers. On the other hand, an array of alternative research programs are coming to the fore that deal with various aspects of the relation between evolution and cognition in promisingly new ways: evolutionary psychology, the adaptive behavior and cognition program (GIGERENZER), reliabilism, regulatory systems theory (HOOKER), situated activity and interactive emergence (HENDRIKS-JANSEN), or memetics, to name but a few. We critically review both EE sensu stricto and some of these newer approaches. We recommend a reflection on the naturalistic roots of EE—the quest for a scientific, that is, anti-transcendent and anti-transcendental epistemology for limited beings—which we hope may inspire a version of EE apt to face the future.

Key words

Adaptation, constructivism, emergent interaction, evolutionary naturalism, evolutionary psychology, regulatory systems theory, situated activity.

"(… et comme un aveugle dont le doigt tâtonne sur le texte de la vie et reconnaît de-ci, de-là, 'ce qui a déjà été dit'.)"—Roland BARTHES

It is appropriate to characterize evolutionary epistemology (EE) broadly as "the naturalistic explanation of cognition" (CALLEBAUT/STOTZ 1999a).[1] This definition encompasses the two interrelated but distinct research programs that are commonly distinguished within EE, viz. (1) the natural-scientific investigation of the hereditary[2] mechanisms responsible for perception, memory, concept formation, reasoning—and other aspects of mentality bearing on cognition, such as emotion—and (2) the (would-be) naturalistic account of scientific evolution, or human social learning and cultural evolution more generally.[3]

If understood in this general way, and assessed in terms of publications output and public reception as quantified by conventional scientometric measures (CALLEBAUT 1999b), EE is doing rather well. But if conceived more narrowly as the systematic elaboration of the programmatic ideas of founding fathers such as Konrad LORENZ, Karl POPPER, or Donald T. CAMPBELL, both EE programs seem to have reached a stage of diminishing intellectual returns.[4] The question may be asked, then, whether EE—considered either as a 'conceptual species' per se or at the level of one or several of its constituent 'populations'—is "progressive" or "degenerative" in the sense of LAKATOS, provided it makes sense at all to view it as a (set of) research program(s).

We suggest that its advocates should resist the temptation to reinvigorate EE by attempting to bring alternative and sometimes competing accounts for the interface between evolution and cognition—such as evolutionary psychology or memetics—under its umbrella. Such a subsumption, we fear, could only *lame* EE. Although innovative and fertile in important ways, these alternative programs are also seriously flawed from the perspective of EE, in that they are affected by backlashes vis-à-vis the main tenets of the *Weltanschauung* which informs EE, and which we take to be worth defending more than ever. (At this deep level, the EE of the Altenberg Circle, VOLLMER's EE and CAMPBELL's "general selection theory" turn out to be remarkably similar.)

What we recommend instead is a critical reflection on the *naturalistic roots* of EE (the quest for a scientific, that is, anti-transcendent and anti-transcendental epistemology for limited beings), which we think may inspire a *lean*, yet powerful version of EE apt to face the future. Such an EE, we think, should deliver itself from certain modernist illusions concerning EE's alleged "implications for humankind" (WUKETITS 1990), yet remain true to the "meliorative"—that is, normative—project that has inspired the great western epistemologies from Francis BACON to the Vienna Circle (cf. HARRÉ 1986; KITCHER 1993).

1. Toward a self-critical EE

EE seems to be thriving. A decade ago, HAHLWEG/HOOKER (1989a, p18) called it "richly diverse, promisingly seminal, and rapidly expanding." The continued opposition of more traditionally-minded philosophers[5] has not prevented EE from becoming "a flourishing field within the philosophy of science" (AZEVEDO 1997, p84), although it is certainly exaggerated to call it "one of Anglo-American philosophy's most flourishing branches", as molecular biologist Derek GATHERER (1997) would have it. The current interest in EE of both lay readers and professionals in biology, psychology, and related disciplines was certainly also partly enhanced (as even a superficial scientometric analysis or Internet search will confirm) by the immense popularity of the hard-nosed and imperialistic 'new DARWINISM' instigated by George C. WILLIAMS and Richard DAWKINS, which enthusiasts such as anthropologist Derek FREEMAN (1996) already see culminating in a "new evolutionary enlightenment" that will "far outshine the enlightenment of the 18th century."[6]

Yet there are some cracks in the picture, which make us doubtful as to the long-term viability of EE if nothing changes. The main reasons for our concern will be offered in a minute. As a preamble we must admit that it is not very clear to us what kind of an animal EE precisely is. "A satellite theory of evolutionary biology" (Hans MOHR), which is how the Altenberg Circle usually views EE, will do as a first approximation only. Both empirical (sociological and historical) and theoretical investigations from Thomas KUHN onwards (SUPPE 1977; LATOUR 1987) have shown that 'theory', whatever its other merits, is an inappropriate and misleading unit of analysis for science studies. The main reason for this deficiency is that conceptualizations of science in terms of mere theory or theory change wholly disregard the psychological and social *embodiment* of scientific knowledge claims, which essentially contributes to the *cohesiveness* that all scientific communities require in order to be viable (cf. HULL 1988): The 'logic' of scientific argument alone does not determine where a conceptual system is heading. KUHN's Janus-faced notion of a "paradigm" which is at once social and cognitive, and related notions such as "research program" (LAKATOS), "field" (DARDEN/MAULL 1977), or "practice" (KITCHER 1993), although problematic in their own ways, are more promising (CALLEBAUT 1993). The diversity of views that qualify as EE is staggering. Compare and contrast, for instance, BARHAM's (1989) "Poincaréan approach" to EE, autopoiesis theory (e,g., MATURANA/VARELA 1980) or its sequel, enactment theory (VARELA/THOMPSON/ROSCH 1992), DELBRÜCK's (1986) view or MILLIKAN's (1984, 1993) biological grounding of mind and language, with 'standard' EE. Impressed by this state of affairs, and anticipating some of the problems we are about to discuss, CALLEBAUT/PINXTEN (1987) called EE a "*multi*paradigm program." Their use of the term *paradigm*, however, suggested more cohesiveness *within* the various conceptual/social systems of EE than actually exists. Our current proposal is to view EE as *a multiparadigm program on its way to become an interfield* in the sense of DARDEN/MAULL (1977). An interfield consists of items of various sorts in addition to theories (strictly speaking, theories are even dispensable on their account): problems and expectations as to how to go about solving them, methods, techniques, models, etc. In DARDEN and MAULL's view of scientific change, *problem shifts* are crucial; problems arising in one field typically occasion the import of concepts, techniques, etc. from another field. As we view it, EE is the attempt to cope with philosophical (mainly, but not exclusively, epistemological) problems by tapping the resources of evolutionary biology, and increasingly also other disciplines, such as developmental biology, anthropology, etc. Inevitably, such a naturalization (cf. section 4, EN1) goes hand in hand with the progressive replacement of the original cluster of problems—in this case, foundationalist epistemology as a concerted effort to rebut skepticist worries—by a new, 'fallibilist' cluster. This 'problem loss' (cf. 'KUHN loss': the abandonment of old problems in a new paradigm) is most clearly stated by CLARK (1986/1997). 'Traditional' evolutionary epistemologists either seem to ignore this problem (e.g., RIEDL/WUKETITS 1987; VOLLMER 1987), or they pay lip service to it (e.g., CAMPBELL 1988, 1997) while occasionally relapsing into foundationalism (e.g., CAMPBELL/PALLER 1989).

2. Deficiencies of EE

We are now ready for a brief discussion of our main discontents with current EE. It will be easily seen that all of these problems are intimately related.

Exemplar wanting. The main deficiency of EE as we know it seems to be a persistent inability to gather the necessary momentum—which is probably more of a sociological than an intellectual problem—to move beyond the programmatic ('philosophical') stage. More than a decade ago

Ronald GIERE observed that what EE was lacking "is a really good KUHNIAN exemplar, a paradigmatic problem solution" (CALLEBAUT/PINXTEN 1987, p.xii). Little or nothing seems to have changed in this respect, and it is difficult to see how such an exemplar could be 'forced'.

Testability deficit. Directly related to the previous is the problem that if the standard of testability—a necessary ingredient of any naturalistic framework worth the name[7]—is applied to the statements of EE itself, much evaporates for want of sufficiently solid groundwork. (CAMPBELL, who insisted on calling his own selection theory "dogmatic"—e.g., in CALLEBAUT 1993, p289—indirectly granted this point.). KUHN's metaphor of the "puzzle solving" at the center of "normal science" is appropriate here: As convincing applications are not 'in place', EE researchers lack the kind of sense of direction which several competing programs in cognitive science have been able to secure. More generally, testability is a problem for all adaptationist accounts of evolution, and EE has a long record of biases in this respect (cf. section 3). A reorientation away from pure theory, taking the form of, say, one or a few medium-sized case studies, might induce improvements here. Re-reading LORENZ's almost forgotten (1943) paper on "The innate forms of possible experience" is worthwhile in this context (although one will reject his political views there): it displays a close acquaintance with workbench science that is lacking in the literature that has become typical of EE.

Lack of conceptual and social cohesiveness. We already intimated that it is not obvious that EE can be cast in terms of a KUHNIAN paradigm or LAKATOSIAN research program. Ultimately this is because EE has been discovered or invented over and over again by independent scholars from many venues, and often remains an occupation of individual "heretics" (CAMPBELL in CALLEBAUT 1993, ch. 7) working in relative isolation and taking little notice of each other's work. This may come as a surprise to some readers. Yet a quick inspection of the bibliographical references in the standard literature will confirm our impression that the amount of *non-communication* within EE is simply astounding, the polymath Donald CAMPBELL being the one outstanding exception. *Linguistic* and, more importantly, *cultural barriers* further contribute to this unhappy state of affairs. Most notably, one should not underestimate the enduring contrast in style, attitude, etc. between Anglo-American analytic philosophy with its roots in empiricism and materialism, and Continental philosophy, which remains under the spell of the transcendental idealism of KANT. (A rather arbitrary example: HOPPE 1988, p16, p18, writes about genetic epistemology and EE as "threatening" important domains of philosophy, and contrasts these naturalized approaches with an interpretation of KANT that is not empirically suspect ["nicht empirie-verdächtigt"].)[8] Needless to say, such a sociological situation is not very conducive to the building of a genuine scientific community. (Some substantial aspects of the EE of the Altenberg Circle, which at one time came closest to the kind of consensus building group KUHN had in mind,[9] will be discussed in section 3.)

Amateur philosophers. If one considers both the nonphilosophical backgrounds of the major original contributors to EE and the massive and persistent resistance of both traditional and postmodernist philosophers and social scientists to EE and related naturalistic enterprises (see, e.g., BAUER 1997), it does not seem exaggerated to claim that EE *would not have come about weren't it for the valiant incursions into philosophical terrain by founding fathers* such as Konrad LORENZ. (LORENZ, by the way, reveled in his role of interloper: "mit großer Wahrscheinlichkeit [bin ich] der geisteswissenschaftlich am wenigsten Vorgebildete in unserer Runde"—LORENZ 1987, p13.) As a result of this historical contingency, the bold statements of the EE pioneers on, say, the realism issue or KANT's philosophy, were preprogrammed to raise hackles among professional philosophers. So be it! In fairness we must add that much of the sophisticated work in EE that is being published today—even if their authors hesitate to label it as such, perhaps because this is not regarded as politically correct—is produced by professional philosophers of biology or philosophers of mind. One example that comes to mind is the fine work on error or misinformation ("How is it possible for physical systems to misrepresent the state of their surroundings?") of authors such as DRETSKE (e.g. 1981, 1986, 1995), DENNETT (1987), GODFREY-SMITH (1989. 1992, 1996) or SOBER (1994), who have concerned themselves with naturalistic semantics.[10] What this seems to suggest is that the very feature that made EE possible in the first place is becoming more and more of a hindrance in an intellectual environment that by and large has endorsed the idea of the difficult but inevitable naturalization of epistemology.

Amateur biologists. Frustration is a two-edged sword: "Wrong ideas … sound reasonable to people who don't know much about evolution, and proliferate in philosophy, sociology, psychology, anthropology, political science and everyday life. It therefore should surprise no one that EE has its share of naive "evolutionary" notions that any sophisticate would disavow." (D. S. WILSON 1990, p38; cf. RIDLEY 1989). 'Two-edged' does not necessarily mean 'symmetrical', though: it is our impression that the scientists' philosophy, however unorthodox, has on the whole contributed more to the elaboration of EE than the philosophers' science!

Persistent tensions between philosophy and science. One way to deal with these tensions is to conceive of the philosophical and scientific aspects of EE as linked but differentiable. For instance, PLOTKIN (1982, p3–4) wrote that "[t]here is nothing contradictory between EE as philosophy, psychology or biology, yet each can be pursued separately. Nor is there anything intrinsically more fundamental to one as opposed to the other." We think that although a "Divided we stand!" strategy may work in some contexts (as SCHWARTZ/THOMPSON 1990 have shown nicely in the case of environmental policy), it cannot be very productive in EE—certainly not in the long run—because of the interdisciplinary nature of the very enterprise. Learning to cope with 'the other' seems to us more to the point than trying to avoid her or his. Somewhere along the continuum from *prima philosophia* ('science is subordinate to philosophy'—cf. MUES 1997) to scientism ('philosophers are but underlaborers for science'), EE should be able to find/create its own niche (cf. LÉVY-LEBLOND 1990, FULLER 1994).

Differential reception. Finally, we want to suggest that any assessment of the impact of EE should distinguish its reception in professional circles with their specific (biological, philosophical, psychological…) agendas from its standing with an informed lay public (*Bildungsbürgertum*), which responds to different tunes. In a secularized society with a growing proportion of educated people, a philosophical-scientific conglomerate such as EE—which offers a cosmology (universal evolution), an epistemology. and the rudiments of an ethical and political view to go with it—is a welcome secular religion for many.[11] In addition, it is rather obvious (although this fact has gone totally unnoticed in the Anglo-American literature on EE) that the remarkable notoriety of the Altenberg group in the German-speaking countries, and to a lesser extent also in Italy and Spain, cannot be understood without connecting it to concerns of an ethical or political nature such as biodiversity, environmental protection, or the anti-nuclear movement, that prima facie have little to do with EE as such.

Interim conclusion. If we may have sounded somewhat harsh in our assessment of the (sociological) state of EE, it is because as sympathethic critics of EE, who participate in this fascinating enterprise ourselves, we endorse evolutionary biologist and philosopher William WIMSATT's view that "if we are to take the variety of ways in which the evolutionary perspective has infused and been used in biology as a model, the directions in which EE has gone so far have exploited but a tiny fraction of the resources available to such a perspective" (WIMSATT in CALLEBAUT 1993, p287). What seems to be called for most if EE is to flourish is the emergence of genuine *interdisciplinarity*. That it *is* possible to avoid "the risk of presenting baby philosophy for biologists and baby biology for philosophers" (BRANDON 1990, ix) is shown by the coming about, in the last decade or so, of a truly symbiotic relationship between biologists and psychologists on the one hand, and philosophers, historians and sociologists of biology and psychology on the other, in the philosophy of biology community at large, where it functions splendidly (cf. BECHTEL 1986; CALLEBAUT 1993; ALLEN/BEKOFF 1997).[12]

3. EE as *Weltanschauung*

DELPOS (1994, 1996), a sociologist, identified 10 "theses" which together are supposed to cover the spectrum of EE in LORENZ' Altenberg tradition. We have reservations about both her factual account and methodology. Specifically, we don't think her (or any other) characterization of a scientific community purely in terms of a set of *statements* ("Thesen-Konstrukt") can access the deep structure and dynamics of its conceptual system (in the sense of HULL 1988), let alone capture its presumed essence or "Grundform" (CALLEBAUT 1998). But we do believe that her account, when duly modified, provides a convenient grid to sort out various claims which together constitute the *Weltanschauung* (in SUPPE's 1977 sense) of the EEs as developed by the Altenberg Circle, CAMPBELL, and other authors. In this section we use this grid to pursue our assessment of EE at a more substantial level.

(EE1) Pan-evolutionism?

On the naturalistic world view of contemporary science, humans are the sole product of material (physicochemical and biological) evolution; therefore EE takes it that their cognitive phylogenesis or "cognogenesis" (HOOKER 1995, p64) is but a natural continuation of their phylogenesis (e.g., RIEDL 1984). Under the spell of DARWINIAN gradualism (e.g., MAYR 1997, p183–184), most EE advocates take for granted that mentality/intelligence/rationality are to be found in nonhuman organisms as well; see, e.g., SOBER (1981); WUKETITS (1990, p90) on BRUNSWIK's "ratiomorphic apparatus"; HOOKER (1987, 1995).

EE thus endorses DOBZHANSKY's famous quip that "Nothing in biology makes sense except in the light of evolution" (in DOBZHANSKY et al. 1977, p.v). This conviction may seem so uncontroversial as to qualify as a background belief—a belief that is no longer questioned or even questionable. This is why we would like to draw attention to the following points:

BURIAN (1988) has pointed out that the *interaction between law and history*[13] requires any satisfactory general theory of evolution to have the peculiar character of a "schematic theory." All that such a theory can provide is a framework for describing and explaining evolutionary sequences and patterns, which must then be filled in by particular empirical analyses of the historical circumstances of specific organisms and their environments. We believe that this important limitation of evolutionary theory—its schematic character—is the flip side of what has made it so successful historically: its 'umbrella' function, as illustrated by both DARWIN's consilience and the Modern Synthesis (KITCHER 1993, E. O. WILSON 1998). Somewhat paradoxically, then, it is one of the positive heuristics of evolutionary theory, its integrative power, that itself seem to suggest the impossibility of an "evolutionary panacea"—a moral that DENNETT (1995) has not drawn!

As a variety of 'ontological' continuity (cf. section 4, EN1), mental continuity is not strictly required from a naturalistic point of view: Mental properties might be made dependent, say, on a level of computational complexity not found in nonhumans. Nevertheless, skepticism about animal mentality (cf. the impressive documentation collected in FERRY/GERMÉ 1994) is "one of a number of pieces of the Cartesian legacy whose defeat would go some way toward vindicating naturalism" (ALLEN/BEKOFF 1997, p12). In this sense, the *comparative method* that favorably singles out Altenberg EE from other approaches (Cecilia HEYES, personal communication) may even be the evolutionary naturalist's masterpiece (see EE5).

(EE2) Systems approach and emergence

Given the centrality of the notion of evolution—which for us basically means that much depends on it "peripherally" (QUINE 1951) or "downstream" (WIMSATT 1986) in models, theories, etc. of biological or cultural evolution—it is particularly important to define evolution in a non-biased way. EE has not always been very careful in this respect (see, e.g., WISPÉ/THOMPSON 1976 on CAMPBELL's selectionist bias). 'The current state of a system resulting from continual change from its original state' comes as close to a neutral definition as one can probably get, but is not very informative. In this context we want to point to RIEDL's comparative approach to EE (e.g., RIEDL 1984, 1987, 1992). which he articulated independently from LORENZ's ethological approach (cf. EE6), grounding it in morphology instead. Morphology (e.g., RIEDL 1977) investigates homologies. It allows to determine the probabilities that enable us to identify single structural compounds ("Komplexe", that is, "modules", in current terminology: WAGNER 1996, GRIFFITHS 1997, pp91–98) of different species. These compounds may be spatially (anatomy) or temporally (behavior, emotions, etc.) structured. Homologies are *constrained* in that they are characterized by their resistance to external selection pressure (e.g., RIEDL 1977). Here we have, at least programmatically, an account of EE that, in being derived from the Systems Approach to Evolution, avoids the pitfalls of adaptationism that characterized, for instance, much of CAMPBELL's or VOLLMER's earlier work (cf. WAGNER 1996).

As an attempt to transcend the dichotomy of external versus internal explanations that is a plague on both the natural and the social sciences (DE MEY 1982, GODFREY-SMITH 1996), the systems approach of the Altenberg Circle—with its roots in Nicolaï HARTMANN's "Schichtenlehre" (HARTMANN 1964; SCHLEMM 1997), Ludwig von BERTALANFFY's organismic biology (VON BERTALANFFY 1968; HOFER 1996), and Paul WEISS's (e.g., 1971) theory of the hierarchical organization of living matter—is avowedly nonreductionistic. But a comparison of LORENZ' "Fulguration" with CAMPBELL's "downward causation" does not reveal major disagreements with the organicist philosophy of mainstream evolutionary biology (MAYR 1982, HULL 1974) or, for that matter, the 'methodological-individualist' approaches of mainstream social science (CALLEBAUT 1999a). With a few exceptions—HULL, RUSE, and in particular WIMSATT (1998)—authors belonging to EE have not contributed substantially to the debate on reduction and emergence.

(EE3) Beyond adaptationism

According to mainstream evolutionary biology, "the DARWINIAN process of natural selection accounts for all aspects of the adaptation[14] of an organism to a particular way of life in a particular environment" (WILLIAMS 1992, P5; cf. RIDLEY 1993).

In his Königsberg paper on the biologization of KANT's a priori, LORENZ (1941/1982, p124–125) wrote the by now famous passage: "If we conceive our intellect as the function of an organ (and there is no valid argument against this) our obvious answer to the question why its form of function is adapted to the real world is simply the following: Our categories and forms of perception, fixed prior to individual experience, are adapted to the external world for exactly the same reasons as the hoof of the horse is already adapted to the ground of the steppe before the horse is born and the fin of the fish is adapted to the water before the fish hatches. No sensible person believes that in any of these cases the form of the organ 'prescribes' its properties to the object." LORENZ' overt adaptationism (and the correspondence realism it entails) may be explained 'externalistically' by referring to the historical circumstances in which he worked: his generation still had to fight for the acceptance of Darwinism (RIEDL 1995, p28). CAMPBELL's case is more mitigated in this respect, as his view of "vicariance"[15]—maybe his most important contribution to EE—opened the door for a 'constructivist' contribution of the subject/organism which he referred to as "internal selection" or, in his later work "local coherence selection" (CALLEBAUT 1999a). One of his favorite examples concerned the "anadaptive speciation" of the Romance languages: "Isolation of portions of an historical entity like a language or a biological species will lead to speciation which need not be (perhaps usually should not be) interpreted as adaptation to differing ecologies" (CAMPBELL 1985, cf. his 1997).

Independently of the correspondence/coherence (cf. EE9) debate and its ramifications (cf. WUKETITS 1990, p96–101: "A Nonadaptationist View of the Evolution of Cognition"), one should be clear about what it is that adaptationism can and cannot explain. In HAUPTLI's (1994, p297) words, "the evolutionary model … really warrants only claims about the fundamental character of that portion of the independent reality which lead to the currently selected traits and practices—on the assumption that these traits are not merely associated with other traits which were selected for *their* survival-conduciveness, and on the assumption that intelligence is not vestigial."

Some authors have suggested an asymmetry between the biological and the cognitive cases that would make LORENZ's rapprochement problematic. As RIDLEY (1989, p360) puts it: "Darwinism does explain how adaptations change through time. However, it is not itself a theory of adaptation." Camouflage, say, is understood as adaptive by simple *design arguments*, not by invoking evolutionary theory. In the biological case, the fact of natural design can be taken for granted. EE, RIDLEY believes, "can take no such thing for granted, however. Epistemology should tell us not just how scientists bring about scientific change; it should also tell us how it happens that, and in what way, scientific theories acually work"—how it solves its problem or explains whatever part of the universe it is concerned with. Part of the problem for the correspondence theorist as well as representationalist (cf. BICKHARD 1998 on the differences between correspondence and representation) is, of course, how to cope with 'world structures' at all: "Jedes sprachlich explizite Abbildungskriterium enthält im Anwendungsfalle auf einzelne Sachverhalte die sogenannten Weltstrukturen schon in einer sprachlichen Form, deren Angemessenheit an die Welt damit ebenfalls bereits unterstellt werden muß" (JANICH 1996, p139).

(EE4) Life as 'knowledge' gain?

At the heart of EE stands the *equivalence postulate*: "life = cognition" (HESCHL 1990; WAGNER 1996). EE is thus based on two basic assumptions about the relation of cognition and its product, knowledge, to evolution: (1) cognition as the ability to acquire knowledge is (the product of an) adaptation, and (2) life (which is usually defined in terms of adaptation) itself is a knowledge-gaining process. D. S. WILSON (1990, p39) tries to associate the first claim—adaptation as knowledge—with EE_2 ("the EET program tends to treat knowledge as the basic product of evolution, with biological adaptations a form of knowledge") and the second—knowledge as an adaptation—with EE_1 ("the EEM program tends to treat the ability to know and the knowledge that it produces as a biological adaptation that in the past contributed to survival and reproduction"), but as his own list of examples (p40) shows, such a simple mapping does not obtain.

Consistently naturalized EE views cognition as a biological process. In contrast to a quite different kind of EE which models the relationship between organic and cognitive processes as a formal analogy, consistent naturalists argue for a *direct embedding* of both processes. The postulate which equates life with cognition is based on the general definition of both of its terms as *information*-gaining processes. Evolution is conceived as an irreversible process in which organisms successively acquire environmental information which they incorporate into their structure. Cognition extends this process as a "special case of information incorporation" (HOOKER 1995, p51). Since we subscribe to the continuity thesis (cf. section 4, EN1) we see nothing wrong with this claim if made at this level of generality. Although 'information' is a somewhat slippery term because it is system-relative, one may agree in this context on a formulation of information as a feature of organisms that "enables internal organization to track environmental regularities and relate them to behavioral output" (CHRISTENSEN 1996, p313). ("Organization" and "behavior" are to be understood here very minimalistically.) Now there are certain properties of a cognitive process which go far beyond the organic level in the way they achieve and control information, and which are not touched by this equivalence claim. Cognition does in fact require *regulatory mechanisms* that are generated and sustained by the internal organization and are quite different from organic organization. These internal structures impose constraints of a particular kind on the evolutionary process to which 'traditional', selectionist EE with its postulated mechanisms of variation, selection and retention (VSR) is blind (CHRISTENSEN/HOOKER 1997). But this theme would lead us to a broader discussion of the theoretical foundations of EE which cannot be pursued at this occasion.

We are dealing with a different version of the equivalence postulate is specified the way LORENZ' did, viz. in terms of a *knowledge* gaining process (see, e.g., PLOTKIN 1992). In this case we find ourselves in a complex debate about the semantic level of information and the question how a system achieves or generates meaning.[16] If EE wants to save the current understanding of knowledge as a kind of 'available' or 'explicit' information over which a system has quite different possibilities of control than over information that is incorporated in a particular shape of body parts, and prefers not to engage in the murky waters of the debate about the relation between the thermodynamical interpretation of biological order and the informational view, it should restrain its claim to the more general formulation of the equivalence postulate in terms of information (HOOKER 1995, p348; for an introduction to the wider field of research on "infodynamics" and evolution see WEBER/DEPEW/SMITH 1988).

Indirectly related to this is the criticism that questions the assumption that accurate perceptions of reality are usually adaptive. It comes from a line of thinking with roots in the vitalistic philosophies of Friedrich NIETZSCHE (DEMPSEY 1997) and George SIMMEL (1895/1982) and culminating in the fascinating current work in *naturalistic semantics* we referred to in section 2[17]. Thus the ecologist D. S. WILSON, who is apparently an independent discoverer of the possible effectiveness of false beliefs (or, more accurately, belief systems), offers the hypothetical example of a "truthful" population in which a mutant gene arises "that causes its bearer to sincerely believe that his enemies are by nature despicable people when in fact they are by nature just like him and are enemies merely because they compete for limit[ed] resources" (WILSON 1990, p39). The mutant being more successful than his truthful rivals, it will spread. As a result, the genetically 'improved' mind will contain "a representation of people that is an adaptive distortion of reality" (ibid.). WILSON's criticism of the "model of reality", that EE and many other social sciences share (cf. LAKOFF/JOHNSON 1998) as demanding a degree of knowledge "far beyond mortal graph" (WILSON 1990, p43), joins our own issue.

(EE5) Empirical access to cognogenesis

EE assumes that both the phylogeny and ontogeny of cognition—cognogenesis and psychogenesis—are accessible to comparative empirical investigation. Secure *description* (LORENZ 1973), the *contextualization* of behavior (which must always be viewed in relation to the specific environmental context to which it has been adapted), and the detailed analysis of one type of behavior in one situation in one species and its subsequent *comparison* with other behaviors, situations, and species were the three "orienting attitudes" (Robert HINDE) of LORENZ' ethology. They are being revived today by people who bear in mind BURIAN's caveat (HENDRIKS-JANSEN 1996, ch. 11; cf. section 5).

EE claims to provide solutions to philosophical problems that cannot be solved by means of 'rational' methods—problems that are said to be 'subjective' because they are circular, have no 'reasonable' starting point. The naturalistic solution consists in offering just this starting point for the investigation, which cannot be found in thought itself but only in the natural process of evolution.[18] The question thus turns from 'what cognition really is' to 'how does cognition come about and gets going'. The generative mechanism, according to EE, resemble basic features of the knowledge process—the equivalence postulate. This is in fact the same predicament that led PIAGET to search for the generative mechanism of acquiring knowledge during individual development, not because he was particularly interested in the child's way of thinking, but—and this may be regarded as a challenge for EE—because he could see no suitable method to acquire information about the process of cognogenesis.

There are good reasons for PIAGET's stance. Evolutionary investigation per se is a tricky business since we try to get information about a process that is no longer observable. Evolutionary biology uses mediating features which are treated as references, such as fossils or comparison with related biological taxa. With respect to cognition we face an even greater problem. Cognition is an unobservable feature that can only be deduced from other, observable characteristics such as behavior (cf. HEYES 1996). But behavior usually does not leave direct 'footsteps' in the fossil record and must therefore in its turn be inferred from other traits which do. These other features are thought to be related to cognition so that they interfere with the cognitive abilities of ancestral form in such a way that they resemble prerequisites for special psychological traits, or can be seen as the result or side effect of cognitive action. (The case of human cognition is even more tricky because of the lack of near relatives for comparative studies.) Taken together, these uncertainties make claims about the evolutionary history of particular cognitive traits so difficult to prove that some skeptically inclined authors have even gone so far as to deny the very possibility of an evolutionary investigation of cognition (e.g., LEWONTIN 1989). This is a radical opinion we do not share, but it shows that the general evolutionary turn in the study of cognition is burdened with its own methodological problems. It seems to us important to realize the distance still to be covered if EE is going to have to address genuine philosophical problems by use of empirical methods!

(EE6) Evolutionary limits to cognition?

The Altenberg position that there are phylogenetically explainable *deficiencies of reason* (e.g., RIEDL 1995) has been criticized for not being able to deal adequately with the phenomenon of *science*. Thus, according to HAHLWEG/HOOKER (1989, p30), the bioepistemology of the Altenberg group has primarily a "remedial function" with respect to epistemology by de-anthropomorphizing it. But "it does not have any positive function… For while it may explain why common sense is successful, it cannot direct our thoughts once we leave the realm of everyday experience." Deploring that bioepistemology offers no insight into the dynamics of cognition, they rhetorically ask: "Should it really be the case that the evolutionary process that shaped the cognitive structures of all species, including our own, cannot provide further guidance once we reach the highest level of cognition as exemplified in science?"

HAHLWEG/HOOKER's reservations are motivated primarily by their naturalistic agenda of doing away with any remaining dualisms as reflected in the 'mechanisms' versus 'theories' dichotomy within EE.[19] As an aside, we should mention that their insistence on the importance of coping with science is amplified by recent considerations coming from *evolutionary archaeology*, which challenges evolutionary psychologists to direct more attention to types of thoughts that appear to be absent in the minds of other animals: *thoughts about art, religion and science* (MITHEN 1996a). According to MITHEN, the archaeological record makes plausible that a "cultural explosion" took place. Rather than having a slow, gradual evolutionary history (as is assumed for language), art, religion and science seem to have appeared rather suddenly. On MITHEN's view, the notion of a modular mind dear to evolutionary psychologists—the idea of the mind as a collection of specialized modules, each geared to solving a specific adaptive problem in our evolutionary environment (cf. section 5)—fits early humans better than modern humans. Neanderhals, for instance, appear to have been unable to integrate knowledge about tool making, social interaction and the natural world. But approximately 40,000 years ago, an immense diversity of tools appears in the archaeological record, at the same time as evidence for art, religion and science. These new types of thinking seem to be a product of what MITHEN (1996a) dubs *cognitive fluidity*: "previously isolated domains of thought now working together."

Both LORENZ and CAMPBELL regarded the evolutionary genesis of cognition as "entailing not only inexactness but limitations in the scope of our knowledge", and STENT "has postulated a limitation on knowledge outside of our evolutionary experience as a way of safeguarding the validity of our knowledge about things closer to home" (LEVINSON

1982, p492).[20] Of the leading evolutionary epistemologists, POPPER was most outspoken in rejecting any form of an evolutionary limitations hypothesis; he equated evolution with *fallibilism* (lack of certainty) and not with any necessary limitation on the range of scientific knowledge. The main argument offered against a limitations thesis is *exaptation*: "so common is the incidence of noncognitive biological structures' performing tasks they were not originally selected to perform, that any claim that our cognitive structures are necessarily incapable of performing well in alien environments is self-contradictory, or based on a mistaken notion of evolution" (ibid.; cf. ENGELS 1989). As will be seen below, the idea of limitations to knowledge is certainly more in the spirit of KANTIAN *Transzendentalphilosophie* than of evolutionary naturalism.

(EE7) A priori/a posteriori

The most basic insight of EE—that we possess a biologically innate knowledge that precedes all experience—was formulated by DARWIN himself, who in one of his notebooks conceived an evolutionary rendering of the Platonic forms (see, e.g., OESER 1995, p270). LORENZ's (1941/1982) biologization of the KANTIAN categories and forms is one of the most controversial tenets of EE. VOLLMER (1984) argued with respect to KANT's a priori principles that they might (!) be constitutive for mesocosmic experience, but that they are not for science. Nor do they limit theoretical knowledge, for we may do without them or even contradict them. According to the mathematician and philosopher of biology Philip KITCHER (1992, p113), the route to naturalism "involves at least a minimal reintroduction of psychology into epistemology (acceptance of the idea that the epistemic status of a belief state depends on the psychological processes that generate and sustain it) and the rejection of the a priori." Prima facie at least, these are two anti-KANTIAN moves. The philosopher of physics Mario BUNGE (1983) even went so far as to claim that by combining the "bad halves" of empiricism and rationalism—phenomenalism and apriorism, respectively—"KANT effected a genuine counter-revolution."[21] To the extent that EE is to be considered a KANTIAN philosophy of sorts, his criticism will have to be extended to it. For most philosophers in the 'Continental' tradition, on the other hand, EE has gone way too far in appropriating KANT for its naturalistic purposes (RIEDL/WUKETITS 1987; PÖLTNER 1993).

To find a way out of this conundrum we want to suggest a 'peace treaty' that allows EE to continue to insist on 'inheritable' cognitive mechanisms, but on the condition that they be redefined in ways that depart from LORENZ' "static universality" (HAHLWEG/HOOKER 1989, p30) and are more in tune with the current state of the art in developmental biology.[22] As our point of departure we take an observation of HENDRIKS-JANSEN's (1996, p222): The conclusion of the early ethologists that "for behavior to be transmitted genetically, it must be totally determined by mechanisms inside the creature, leaving no room for variability" is false, for "variability does not constitute an argument for or against the behavior's having been inherited." Variable, but recognizably structured, behavior "may emerge from low-level reflexes that are quite rigid … and rigid behavior can be learned" (p222). A similar lesson can be learned on the basis of WIMSATT's (1986, 1998) "developmental lock model of generative entrenchment" (CALLEBAUT/STOTZ 1999). How can the concept of heredity be generalized appropriately for the purposes of EE?

That genes are the only factors that construe a heritable relationship between generations is no longer the only view. The *received view* describes the evolution of complex multicellular organisms as dependent on a developmental cycle arising from a single cell bottleneck and to be transmitted through another such bottleneck. Environmental information may be regarded as *developmental resources* that can be interpreted as the necessary background conditions for the genetic information to work properly. Developmental resources are 'informative' in the passive sense of providing a necessary context for the 'real' information on the way to the next generation (e.g., DAWKINS 1982).

A more widely conceived *developmental systems view* treats nongenetic developmental resources as equally important to the course of evolution as genetic resources. JABLONKA/LAMB (1995) draw attention to a large range of inherited characters at the cellular level *besides* the genes, which play an important role in the replication of DNA without being themselves encoded by DNA sequences. These epigenetic resources are chromatin banding, methylation assembly, and the microtubule organizing center. Along with other factors they form the epigenetic inheritance system; they can channel the transmission of nongenetic heritable variation by working directly on DNA (JABLONKA/LAMB 1995; GRIFFITHS/GRAY 1997; GRIESEMER 1998). MÜLLER (1994) and NEWMAN/MÜLLER (1999) argue for a wider conception of epigenetic mechanism at the cell metabolism and tissue level which they regard as mainly responsible for the evolution of morphological prototypes. A famous example of nongenetic heredity at the populational level concerns fire ants: Differences in the size and number of its queens between colonies of the fire ant solenopsis invicta—which could be shown to be nongenetic by means of an exchange experiment—are due to the particular pheromonal environment each kind of colony produces. Since in natural circumstances queens will not be exchanged between colonies, a nongenetic variation has become a stable—inherited—developmental resource (GRIFFITHS/GRAY 1997, p472f).

In addition to metabolic and other internal mechanisms of the cell machinery, developmental system cope with external conditions and factors—geological, ecological, artificial, social, cultural—as well (OYAMA 1985; GRIFFITHS/GRAY 1994, 1997; JABLONKA/LAMB 1995; STERELNY/SMITH/DICKENSON 1996).

The assumptions supporting this view are novel in two important ways: (1) The gene-centered view of heredity focuses on the *isolated* individual that is only capable of transferring packages of preformed information through the mating act. A multilevel perspective of organization, in which cells, individuals, and groups can exist at higher levels, takes into account a whole range of different stable relationships and hence allows for other kinds of transgenerational exchange of nongenetic but heritable information. Here one could envisage a rapprochement with the systems approach of EE, and possibly also a reformulation of LORENZ' and others' dated views on group selection in the WYNNE-EDWARDS tradition. (2) The new, epigenetic view attempts to release the developmental system from its traditional *passive* and 'internal' role of solely receiving and transforming two-channeled information (gene and environment). In the "constructivist interactionist vision of ontogeny and of phylogeny" (OYAMA 1999), the organism is being replaced by an active and interactive developmental cycle which "progressively influences the conditions for following interactions, and therefore for the organisms' own futures" (OYAMA 1999). This view of an organism as *object and subject of its own life and evolution* was already argued for by LEWONTIN (1982) in a article that has become a classic.

(EE8) Realism/constructivism

It would be ludicrous, given the profusion of positions on the cluster of metaphysical, semantic, and epistemic issues associated with the realism issue that are being (or have been) advocated in the name of 'evolution', to even try to begin to tackle this issue here (but see CALLEBAUT 1993, section 4.3 and 1995 for an attempt to create some order in this labyrinthine debate). These positions range from a metaphysical realism married to a naive 'mirror theory' of experience (e.g., LORENZ 1941/1982, 1943; VOLLMER 1985) via Popperian critical rationalism (e.g., MUNZ 1993) to 'constructive realism' (GIERE 1988), neo-Humean empiricism (RUSE 1986), and more or less radical varieties of constructivism (e.g., DIETTRICH 1989; PESCHL 1994). Moreover, we are convinced that some of the attempts within EE to have one's cake and eat it, by trying to reconcile "correspondence" and "coherence" (e.g., RIEDL 1977, 1992)—are doomed to fail because as a third-person account they cannot deal with the real constructivist challenge (CALLEBAUT/STOTZ 1999a).

A most admirable attempt to undermine the "scientific realism" associated with some of the main varieties of EE (including the EE of the Altenberg Circle) is THOMSON (1995), a student of the constructive empiricist Bas VAN FRAASSEN, who is the major spokesperson for the antirealist position today. The realist THOMSON combats "is committed to the view that science is progressing toward a theory, or toward a well integrated family of theories, which should be regarded as a literally true account of the world" (THOMSON 1995, p165). According to THOMSON, replacing KANT's "ordered by our Creator" (in the concluding remarks to the "Transcendental Deduction [B]", Section 27) with "ontogenetically a priori but phylogenetically a posteriori" gives "a not uncharitable characterization" (p175) of both Michael RUSE's[23] and the Altenberg Circle's programs in EE.[24] KANT asked whether, against his own 'necessitarian' view, the categories might be thought of as "a kind of preformation-system of pure reason" (THOMSON), viz., as "but subjective dispositions of thought, implanted in us from the first moment of our existence, and so ordered by our Creator that their employment is in complete harmony with the laws of nature in accordance with which experience proceeds." KANT rejected this possibility because he "would then not be able to say that the effect is connected with the cause in the object, that is to say, necessarily, but only that I am so constituted that I cannot think this representation otherwise than as thus connected"—which "is exactly what the skeptic most desires." But isn't this exactly the position of EE? If we have "transcendental deductions that go through only because we are prisoners of our own perspective, then that will be a Pyrrhic victory indeed", VON SCHILCHER/TENNANT (1984, p194) write. The situation of "LORENZ and company" is actually even worse than the preformationist alternative that KANT considered, THOMSON maintains, "for on the latter program one could at least have a moral certainty that our categories harmonized with the world, whereas the evolutionary epistemologist can give no assurance" (p175).[25] Once again, it is the *adaptationism* associated with EE that receives the flak: "He who espouses an evolutionary account of our cognitive structures as the best explanation of the a priori is an optimistic KANTIAN indeed if he does not carry over to the mental the unsentimental lessons evolutionary theory teaches us about adaptation at the morphological level. *EE can be expected to render revealed reason all the more vulnerable, all the less ideal, for being the product of our evolutionary past.*" (VON SCHILCHER/TENNANT 1984, p195; italics ours).

Tempting as this conclusion may seem, we remain unconvinced. In paticular, the argument that leaps from the exaptation or preadaptation of our brains/minds (cf. the ratiomorphic apparatus) to the denial that the minimal competence of the human brain at representing and reasoning about nature which evolutionary naturalism requires (cf. sections 4 and 5) "will take us very far in establishing the reliability of the historical process out of which contemporary scientific beliefs have emerged" (KITCHER 1993, p300; cf. VAN FRAASSEN 1989, p143–144) may be turned against its originators. Thus none other than GOULD himself has invoked exaptation to deny any 'evolutionary limitations' thesis with respect to the scope of human knowledge (see, e.g., ENGELS 1989, pp329–330).

Not even HOOKER's (1987) sophisticated defense of "evolutionary naturalism realism" is acceptable to THOMSON (1995, pp177–178), who writes that "HOOKER's argument for being a scientific realist … depends upon the notion that one can accept a theory as literally true while remaining agnostic or skeptical about any particular research program at the 'meta-level'… However, I don't see how one can prevent the skepticism of the 'meta-level' from 'infecting' one's attitude toward the particular theory at the lowel level." Here is one juncture where we witness the breakdown of the rules of the philosophical game, for as principled fallibilists, consistent evolutionary naturalists no longer have the *ambition* to answer the skeptic. Check, in particular, GIERE (1988, 1999), HULL (1988) and FULLER (1988, 1996) on the progressive shift, within recent naturalistic studies of science, from the quest for (1) epistemological *foundations* (undermined by both QUINE's critique of empiricism and KUHNIAN historicism) to (2) (predominantly social) *justification* (cf. 'legitimation') to (3) *explanation*. One way open to the naturalist to escape from this imbroglio is to ask whether the realism-instrumentalism debate has, at this stage, any *testable consequences*? If not, why bother? Here we must endorse HULL's (1989, p320) assessment: "I doubt that anything that might count as data or evidence could possibly influence the debate over instrumentalism and realism. These positions have become way too sophisticated. No matter what course the history of science takes, all sides will be able to claim victory." Against this background, one might consider redefining the rules of the game by turning away from armchair philosophizing and (re)focusing instead on how scientists deal with matters of existence and 'local reality'.

(EE9) Ethical and political implications

As any other world view, EE comes as a package deal that offers answers to societal and existential questions, and owes much of the credit it has—especially in the wider culture—to just that. Thus, for instance, EE is being presented as occupying a privileged vantage point in the world. "As the reader might have recognized, this epistemology is not just one of many epistemological schools but rather an attempt to trace back to the *elements* of human nature. So let us see what lessons EE actually can teach us with regard to our self-conception", WUKETITS (1990, p205) declares rather pontifically. Likewise, the author of a recent book on memetics is convinced that he has a message of historical importance to convey: "The present book aims to expand memetics far beyond an academic curiosity by examining its vast relevance to how society thinks and lives. A treatment of this new field can presently offer just an outline, a thumbnail sketch of a far-reaching science. Yet seeing the new paradigm linked with so many important aspects of life imparts a revised worldview, one that renders apparently arbitrary currents of culture freshly comprehensible" (LYNCH 1996, p3) Especially in the hands of highly visible members of the scientific elite, the ethical and/or political message may even become preponderant in terms of public impact. It is LORENZ' *On Agression* (1966) or *Civilized Man's Eight Deadly Sins* (1973), not his *Behind the Mirror* (1977), that one finds at airport newsstands.

We suggested before that it would be interesting to investigate somewhat systematically how the various programs in EE function at this level. We assume that the idiosyncratic role the Altenberger Circle plays in this respect cannot be fully understood without taking into account the different roles an ordinary professor plays, even today, in, say, a German or Austrian setting—where he or, more seldom, she is typically held in high esteem as a *Kulturträger*—and in an American setting—where technical expertise in some rather narrow area is what matters most. (There are obviously exceptions to this generalization.) One striking difference, if one compares LORENZ's and CAMPBELL's wider intellectual impact, is that whereas the ethologist was a truly public figure known to the man or woman in the street, the social psychologist's societal concerns were always channelled through professional institutions. CAMPBELL's sympathies for the "honest" political leaders of the DUBCEK era in Czechoslovakia are but mutedly expressed in his essay on "The Experimenting Society" (in CAMPBELL 1988, p290–314). His concern about the erosion of evolutionarily acquired "wisdom" was publicized at the occasion of his Presidential Address to the American Psychological Association in 1975 (CAMPBELL 1975a).[26]

In his "Reintroducing Konrad LORENZ to Psychology", CAMPBELL (1975b) praises LORENZ' conceptualization of socially organized intergroup agression as "a valuable contribution to the social science theories of intergroup conflict, ethnocentrism, war, and genocide" (p102), but disagrees "with many of the implications of the brief and casual comments on genetics that LORENZ makes" in *Eight Deadly Sins* and elsewhere (p111f). E.g., pace LORENZ, eyeglasses have "greatly increased" our "over-all species adequacy in the area of vision" (p111), and domestication can be regarded in a positive light as well: "Urbanization is the more appropriate term here… to regret that this process [of genetic and cultural adaptation] is removing specific adaptations to specific regionally different ecological niches, as LORENZ seems to, is foolish when these ecological niches no longer exist" (p113). Without anticipating the eventual results of the kind of study we are calling for, we think that exchanges like this one[27] suggest once again the necessity of an *interdisciplinary* approach to EE, which alone can compensate for the biases that almost inevitably hamper any individual scientists' work, and anticipate communication problems. As the system dynamics community who produced the reports to the Club of Rome made amply clear in the 1970s, the task of coping with the complexities of the "counterintuitive behavior" of the social systems on our planet (Jay FORRESTER) is too titanic to be handed over to a handful of intellectuals working in the splendid isolation of their study rooms (cf. BRÜGGE 1989).

4. Back to the Roots: Evolutionary Naturalism

Having completed our (admittedly oversimplified) critical survey of the EE *Weltanschauung*, we now want to invite the reader to take one more step back and reflect on the various aspects of Evolutionary Naturalism that underpin EE, or at least the kind of EE we would like to see emulated.

In a departure from almost four centuries of *Subjektphilosophie*, Evolutionary Naturalism (EN) takes it

(1) "that the physical world exists independently of our knowledge of it (Material Realism)",

(2) "that our knowledge of the world proceeds from a distinctively human and limited point of view and hence that our conceptions of reality are never fully accurate or unbiased pictures of the world as it really is (Cognitive Bias and Limitation)";

(3) "that other beings may process and assess information in ways which give rise to thought and experience which is in some sense alternative to our own (Conceptual Scheme Realism)" (CLARK 1984, p483).

EN regards the physical world at large as a natural unity that includes human beings and their minds as an integral part (e.g., QUINE 1975; MILLIKAN 1984).[28] The naturalistic epistemology and metaphysics are neither intuited nor the result of some transcendental deduction, but derived from our current scientific understanding, using a 'third person' perspective,[29] of inorganic, organic and cognitive evolution (CAMPBELL 1988, 1997). On such a view any idea that the human mind has access to truths that are independent of investigation or somehow transcend it are just "hangovers of superstition" (Dudley SHAPERE in CALLEBAUT 1993, p69).

The naturalistic understanding of the philosophy of science is also based on a peculiar but plausible interpretation of the historical relation between science and its philosophy. On this view science is a *self-corrective* activity, and the theory of science may be viewed as a sort of 'metalearning module' that allows science to 'learn how to learn'.[30] This research strategy, which regards ontology as theory-dependent, is in line with QUINE's "ontological relativity", and more generally with the naturalist's *rejection of any first philosophy whatsoever*.

We have found it useful to distinguish the following, more or less independent 'dimensions' of naturalism.

(EN1) Explanatory continuity

Philosophical naturalism has meant many things to many people. The authors we consider here are all agreed with QUINE that naturalism implies banishing the dream of a 'prima philosophia' and pursuing philosophy rather as part of one's system of the world, continuous with the rest of science.

This at once implies that the naturalistic philosophy should aim to be a *testable* theory (GIERE 1988, 1989; PLOTKIN 1991). If science, as we may confidently assume, is a most successful epistemic enterprise that is constantly being revised, then it follows that understanding its workings demands a fallibilistic view, which in turn requires testability. (Historically, the possibility of testing was contrasted with relevatory experiences that were not open to all.) GHISELIN's (1983, p362–363) insistence on the testability of "post-Spandrel adaptational biology" (ROSE/LAUDER 1996a) may be seen as a biological application of QUINE's (1951) ban on the use of analytical statements in science because they lead to 'immunization' and hence hamper progress (cf. EN3): "Competent biologists treat the occurrence of adaptation or maladaptation as contingent… Adaptation has to be hypothesized and tested like everything else in science… The new adaptational biology is neither Panglossian nor pluralistic, but tests broad, general hypotheses against hard data and is not satisfied until all contradictions have been purged from the system." Still in line with QUINE's view, naturalistic approaches to science may be properly seen as contributions to an emerging 'science of science',[31] but many naturalists shun this term either because of its scientistic connotations or because they feel the field is immature (cf. HARDCASTLE 1994).

Continuity is the key to understanding what naturalism is all about. Thus the *Encyclopaedia of Philosophy* defines naturalism (in recent usage) as "a species of philosophical monism according to which whatever exists or happens is *natural* in the sense of being susceptible to explanation through methods which, although paradigmatically exemplified in the natural sciences, are continuous from domain to domain of objects and events" (DANTO 1967, p448). This definition blends explanatory naturalism ("science must avoid non-natural explanations") and methodological naturalism ("science must assume that everything observed is amenable to a naturalistic investigation"). In line with (1) the KUHNIAN insight that methodological values in science do not and cannot function as *rules* (CALLEBAUT 1995b), (2) the recognition in post-empiricist analytical philosophy of science that a plurality of methods is being used throughout the sciences (STEGMÜLLER's 1983 "sixth dogma of empiricism"), and (3) the reorientation of philosophy of science toward mechanistic explanation (CALLEBAUT 1995c; STOTZ/CALLEBAUT 1999a,b), we prefer to talk about *explanatory* continuity.

Although more varieties of continuity can be disentangled in principle (MOSER/TROUT 1995a, p9), most of the debate concerning the pros and cons of the naturalistic stance has been focused on the relation between *methodological* naturalism on the one hand and ontological or metaphysical naturalism ("all that exists is natural"—cf. EN2) on the other (PLANTINGA 1991. 1993, 1996; POST 1995; SCHAFERSMAN 1997). Although there are obvious historical connections between EE and materialism,[32] HOOKER (1987, 1995) and others have argued convincingly that naturalism is not logically committed to materialism (or any other ontological position, for that matter). The methodological or explanatory assumption of naturalism can be accepted for science without thereby invalidating non-naturalistic ontologies outside science. Ontologies outside science have sometimes been considered a matter of personal choice.

It follows directly from the continuity view that *naturalization is a matter of degree*. Consider the debate concerning intentional explanation in animal behavioral ecology (ALLEN/BEKOFF 1997). On the most austere, empiricist interpretation of 'the language of natural science' (an idealization!), mature natural science uses only *extensionalist* language. Naturalism may accordingly be viewed as the doctrine that restricts the language of science to extensionalist notions. QUINE has consistently advocated the total elimination of all kinds of intentions, intensions, meanings, essences, and conscious mental events. The problem, of course, is that even our picture of physics will be very much diminished by a QUINEAN naturalization sand bath. (To QUINE's "ontology of the desert", WIMSATT opposes an "ontology of the tropical rain forest"; see CALLEBAUT 1993, p133f) Others, such as HINTIKKA, have therefore allowed (hierarchies of) sets of possible worlds in their theories; their main concern is rather with the reduction of intention to extensional semantics. A third grade, which is naturalist by courtesy only, comprises the views of those who accept such Fregean entities as 'sense' and 'proposition' and who wish to comprehend intentionality without invoking entities not already supposedly called for by the intensional aspects of language. It is clear, then, that in cases such as our example of intentionality in nonhuman nature, naturalists are in no position to *prescribe* the scientists what they should or should not do.[33] The naturalist rather witnesses (as he or she thinks it should be) the debate and records a gradual but seemingly inevitable progression of causal-mechanistic explanations, which now supplant intentional explanations. DENNETT has aptly labeled the latter "killjoys" (CALLEBAUT/STOTZ 1999b). Technically speaking, a killjoy is an explanation of the apparently intentional behavior of animals in terms of purely causal physical mechanisms. The exemplar is, of course, DARWIN's 'teleonomic' explanation of teleological achievements by means of his mechanism of evolution by natural selection. A more recent illustration would be the "general demise" of learning, understood as instruction, which PIATTELLI-PALMARINI (1989, p1) takes to be "uncontroversial in the biological sciences, while a similar consensus has not yet been reached in psychology and in linguistics at large." And what HENDRIKS-JANSEN (1996, p209) calls LORENZ's "naturalistic compromise between mechanicism and vitalism"—his decoupling 'action-specific energy' from 'goal directedness'—may be seen as yet another killjoy.[34] Our examples also makes clear that philosophy is, or is not, naturalized *with respect to the science(s) of a given time*. Since the substantive content, methods, etc., of science change, what is considered '(non)natural' today may no longer be so tomorrow.

A last important observation in this context is that continuity is *symmetrical*. The circumstance that the naturalist looks first and foremost to the methods or explanations that DANTO saw "paradigmatically exemplified in the natural sciences" is a matter of historically contingency (the earlier and greater success of the natural sciences in comparison to the social sciences and the humanities), not of logical necessity. A new kind of rapprochement finds its rationale in the uncovering of the hermeneutical nature of many natural-scientific procedures (KNORR CETINA 1981; cf. RIEDL 1985). In principle—*les extrêmes se touchent*—naturalism and culturalism (JANICH 1996) should amount to the same!

(EN2) Against transcendence (combative naturalism)

The second, combative dimension of naturalism is the postulate of the worldliness (*Diesseitigkeit*) of all human cognitive endeavors—CZIKO's (1995) "Without Miracles." LORENZ (1941/1982) himself dubbed his biologization of the KANTIAN apriori forms and categories an "attempt at natural explanation" as opposed to one in terms of "supernatural factors" or Platonic ideals, that is, unchanging factors shaped by God. He proposed to reinterpret his explanandum, the *Vernunft*, naturalistically as a "(function of an) organ or an apparatus." In some of his other earlier work his anti-transcendent stance is even more outspoken.

Actually naturalizing some of our cognitive categories is much easier said than done. According to MILLIKAN (1984, p325–333), even QUINE has not been able to escape "meaning rationalism".

Considering the rise of religious fundamentalism throughout the world, it is not just the apparently universal compulsion of the human mind to come up with ideas about gods, spirits, and an afterlife that needs attention; it is "the remarkable resilience of such ideas in face of evidence to the contrary that is so baffling from an evolutionary point of view" (Steven MITHEN).

(EN3) 'DeKanting' (liberatory naturalism)

A basic naturalistic theme is to show that "possibilities are open rather than, as in traditional philosophy, to define the—preset—*scope and limits* or the fundamental necessary assumptions of science" (SHAPERE in CALLEBAUT 1993, p68). In this respect, the 'bio-KANTIAN' EE of the Altenberg Circle seems to sit square with the naturalistic vogue. One of the clearest statements of this 'liberatory' dimension of naturalism we have found in the sociologist's Niklas LUHMANN's *Die Wissenschaft der Gesellschaft* (1990), where LUHMANN identifies a naturalized epistemology with a de-transcendentalized one. He also relates the 'transcendental/natural' dichotomy to the reflexivity of a theory: "Ungeachtet aller spezifischen Theorieannahmen (Bewußtsein, Vernunft, Subjektivität betreffend) kann man eine Theorie als transzendental characterisieren, wenn sie nicht zuläßt, daß die Bedingungen der Erkenntnis durch die Ergebnisse der Erkenntnis in Frage gestellt werden. Transzendentale Theorien blockieren den autologischen Rückschluß auf sich selber. Als empirisch oder als naturalistisch kann man dagegen Erkenntnistheorien bezeichnen, wenn sie für sich selbst im Bereich der wissenswerten Gegenstände keinen Ausnahmezustand beanspruchen, sondern sich durch empirischen Forschungen betreffen und in der Reichweite der für Erkenntnis offenen Optionen einschränken lassen." (LUHMANN 1990, pp15–16)

WITTGENSTEIN's statement in the *Tractatus* (4.111), "Die Philosophie ist keine der Naturwissenschaften. (Das Wort 'Philosophie' muß etwas bedeuten, was über oder unter, aber nicht neben den Naturwissenschaften steht.)", might stand as an epitome for the very position the naturalist combats. For rebuttals of the classical objection that naturalism is viciously circular, see, e.g., VOLLMER (1985) or NICKLES (in CALLEBAUT 1993, ch. 5). Note that 'de-transcendentalized' or "deKanted" (Ken BINMORE) is not synonymous with 'anti-foundational' in a wider sense.[35] Thus, in work in progress, WIMSATT is articulating his general model of "generative entrenchment" (WIMSATT 1998; CALLEBAUT/STOTZ 1999) in the direction of a new "dynamical foundationalism." There are interesting parallel developments within biology here, where "inborn" has been associated with "genetic providentialism", as in CZIKO's critique of certain approaches to immunology on the one hand, and to concept and language acquisition on the other (CZIKO 1995, ch. 15: "The Innatist Construal of Selection"). Both WIMSATT's and CZIKO's accounts allow for considerably more flexibility than the static foundationalism they are criticizing.

In the recent history of analytical philosophy, QUINE's (1951) paper, "Two Dogmas of Empiricism", was largely responsible for freeing epistemology from some of its restrictions (viz., the analytic/synthetic and empirical/theoretical dichotomies). STEGMÜLLER (1983) suggested to give up some more empiricist strictures in order to rehabilitate the normative, and effectuate a pragmatical-empirical turn. An interesting consequence of abandoning some of these strictures in the context of EN is that within a scientific-realist framework, the conventionalist arguments of POINCARÉ in favor of the essential *invariability of the fundamental laws of nature* lose their apodictic force (BALASHOV 1992).[36]

(EN4) Bounded rationality

Naturalism's insistence on open possibilities is *not* at odds with the recognition that our knowledge of the world proceeds from a distinctively human and limited point of view (CLARK's "Cognitive Bias and Limitation"). The naturalist's point is that we can (learn to) find out about our limitations as well, and that in many cases, constraints turn out to be enabling rather than restricting courses of behavior or paths of evolution.

Here we want to call on Herbert SIMON's theory of *bounded rationality* or *satisficing behavior*, which he developed with the avowed aim to replace the unrealistic rationality assumptions of conventional social science with an empirically adequate principle. Evolutionary considerations are at the basis of SIMON's satisficing theory (cf. HERRNSTEIN/MAZUR 1987): the survival of human beings depends on their attending selectively to their environment, and on finding satisfactory behavioral alternatives for handling the problems to which they attend. It is the *complexity* of our environment and the *uncertainty* about the world and about the consequences of our possible or effective actions that compel us to learn to live with *satisfactory* rather than optimal solutions to our problems. In the dynamical version of SIMON's theory, levels of aspiration are adjusted in terms of the success or failure of previous attempts to reach satisfactory solutions.

Space limitations prevent us from discussing the satisfacing approach in any detail here, or to spell out even its major consequences for biology and the social sciences (but see CALLEBAUT 1998a). We shall mention only that the temptation has always been to diminish the threat posed by bounded rationality by interpreting satisficing as a case of optimization subject to constraints, as, for instance, John MAYNARD SMITH and other adaptationists have proposed. But one can prove mathematically that such a reduction must lead to an infinite regress (CALLEBAUT 1998a, p88–89). Moreover, empirical investigations (GIGERENZER/GOLDSTEIN 1996) have shown that "simple satisficing strategies can make about as many accurate inferences about real-world environments as computationally costly rational calculations, and in less time and with less knowledge", as GIGERENZER (1997, p269) summarizes this work.

EE, and naturalistic epistemologies more generally, may benefit from adopting the satisficing approach (GIERE 1988; CALLEBAUT 1993; WIMSATT 1998), which by and large they have disregarded until now. (For instance, there has been little sensitivity, as far as we are aware, to the pitfalls of optimization in the context of the 'new' adaptationism.) In addition to cognitive psychology (cf. GOLDMAN 1993), some of the work coming out of evolutionary economics could be inspiring here, such as theoretical and empirical investigations of technological paradigms and regimes (CALLEBAUT/VAN MEER 1998): The sense of constraints implicit in a regime focuses the attention on certain directions in which progress seems possible, and provides guidance as to the tactics likely to be fruitful for probing in that direction. And ANDERSON's (1991) work fruitfully links KUHNIAN paradigms to the bounded rationality theme.

(EN5) Evolutionary grounding

As late as 1955, the philosopher Ernest NAGEL was convinced that epistemic warrant "does not derive from a faith in the uniformity of nature, or any other principle with cosmic scope", and that "there is no one 'big thing' which, if known, would make everything else coherent, and unlock the mystery of creation" (quoted in ROSENBERG 1996, p3). NAGEL was not only an early philosophical naturalist, but also a keen observer of the wider scientific and intellectual scene. Should we conclude, then, that it would have taken clairvoyance—a power that is not within the naturalist's reach—to anticipate the current vogue of EE and omnipresence of evolutionary theory?!

5. By way of conclusion

To positively round off our critical assessment of EE, we briefly survey a number of developments we think EE could benefit from taking into account, without therefore having to assimilate them.

Evolutionary psychology in the spirit of BARKOW/COSMIDES/TOOBY (1992) defines human nature as the set of universal, species-typical information-processing programs that operate beneath the surface of expressed cultural variability. Grounded on findings and speculations from paleoanthropology concerning the mate selection, language acquisition, tool use, and cooperation of Pleistocene hunter-gatherers, it proposes a *modular conception of the human mind* as an intricate network of functionally specialized "computers" (cf. "DARWINIAN algorithms") each of which imposes structured content on human organization and culture. As the successor program to WILSON's human sociobiology. evolutionary psychology is strongly adaptationist. TUDGE (1996) writes that his "brushes with classical genetics" lead him to expect human beings to "have an underlying behavioural program that has been shaped by natural and sexual selection, which does lend itself usefully to DARWINIAN analysis; but also creatures endowed with a thinking machine that is, frankly, unruly. We might even predict that the people with the least predictable, most unruly brains might for various reasons rise to the top of their societies and influence them most." He feels, then, that "the DARWINIAN agenda should be pursued as far as it will go, and indeed beyond", although he is also convinced "that it will, at various points, run into the desert sand, and that we will still need explanations that seem to owe little to evolutionary theory."

The Adaptive Behavior and Cognition (ABC) Program. Support for the modularity thesis as opposed to the traditional view of a domain-general, general-purpose mind comes from the aforementioned work by GIGERENZER and his colleagues, who model the cognitive modules which integrate perceptual, inferential, emotional and motivational processes for particularly important adaptive problems, such as social contracts or mate choice. (Contrast VELICHKOVSKY's 1994 more moderate view of levels of mental processing.) The ABC program seems to us to share evolutionary psychology's individualist bias (as criticized by WILSON/SOBER 1994) and neglect of ontogeny, although research on early infancy may offer the strongest support for modularity (cf. GARDNER 1997). It shares the concern of AI researchers such as CLARK with *external representation*. (According to CLARK's 1989, p64, "007 principle", which echoes SIMON, evolved creatures "will neither store nor process information in costly ways when they can use the structure of the environment and their operations upon it [instead]…. That is, know only as much as you need to know to get the job done.")

Reliabilism (DRETSKE, GOLDMAN et al.) seems to have become many a philosopher's via regia to problems at the interface of evolution and cognition (see, e.g., CLARKE 1996; GODFREY-SMITH 1996). Strangely enough, advocates of EE seem largely unaware of its existence.

The poverty of memetics. Although there is a spectacularly growing literature on the subject of the 'autonomous evolution of cultural traits, especially on the Internet, DAWKINS' 'cultural' brainchild cannot be said to have reached any maturity as of now, even if some enthusiasts think differently (see, e.g., DAWKINS 1976; 1991; DENNETT 1995, p352f: "Could There Be a Science of Memetics?"; WILKINS 1998). Hailed as the 'nonreductionist' cultural complement to DAWKINS' grimly reductionistic view of our genetic evolution, by lack of a theory capable of imposing structure that also plagues general selection theory, memetics remains at present a 'meme bag memetics'. To make matters worse, it shares all of the problems that characterize Popper's World Theory theory (CALLEBAUT/STOTZ 1999b), which caused the Popperian strand in philosophy to be cut off from the interesting approaches to science, technology and society (STS) that have been developed in the last two decades.

The epidemiology of cultural attraction (SPERBER 1996) may be viewed as an attempt to articulate an interfield theory at the interface of anthropology and psychology that allows to answer some of their respective traditional questions, and to formulate new common questions. SPERBER gives a greater role to psychological mechanisms in cultural evolution than does memetics. More particularly, he challenges three core assumptions of the cultural evolution approach. (1) The assumption that culture is made up of *specific units* such as memes he counters by arguing that the units most relevant to cultural evolution are the token mental representations and the token public productions that inhabit a human population and its environment. These are by no means "intrinsically cultural"; in fact, nothing is. (2) *Transformation* rather than replication: SPERBER does not deny that replication may occur. He grants that mental representations and public productions "may cause the tokenings of descendants that more or less resemble them." But he proposes to view replication as a "limiting case of null transformation", processes in the causal chains linking mental representations and public productions being best seen as processes of transformation. "Explaining culture is, then, a matter of explaining under which circumstances there occurs a relative stabilization of form or content in the generation of representations or productions" (ch. 5, "Selection and Attraction in Cultural Models"). (3) As an alternative to the *selectionism* of DAWKINS et al. SPERBER proposes to describe the causal chains of mental representations and public productions "as moving, with each transformation, over a space of possibilities" in which there are attractors such that "in their vicinity, transformations tend to be of limited amplitude and to cancel one another out, mimicking replication." His attractors have quite diverse etiologies, some being constant across cultures and time, other being culture-specific and precarious. The main force driving cultural evolution is the selective stabilization brought about by these attractors. SPERBER also argues for "massive modularity" and tries to show that "strong, genetically determined, cognitive predispositions, not only are quite compatible with the kind of cultural diversity we encounter, but even contribute to the explanation of this diversity" (ch. 6).

Regulatory systems theory (HOOKER 1987, 1995) attempts to lay to rest the ghost of dualism which resists full extinction even in stronger versions of EE. Extant EE, according to this account, does not succeed in fully integrating the cognitive into organic evolutionary theory. Only an "embedding approach" such as that of the Altenberg Circle promises a naturalistic solution, but it fails because of its "obsession" with innate traits and their unquestioned identification with *universal* and unchanging principles (HOOKER 1995, p36–37). Second, its commitment to the population-centered view of evolution as given by the Modern Synthesis leads to the exclusion of individual development and hence of the phenotypic level in its actual environment. The phenotype, however, is important to understand the interactive dynamic of adaptive processes that occur between a system and its particular *context* (HOOKER 1995, p41; cf. MÜLLER 1994). A full-fledged naturalism ought to overcome these artificial gaps by focusing on the regulatory processes leading to stages or product states such as particular organic or cognitive traits on either the individual (sub-system) or populational (system) level, and their dynamical relationships.

Such a unified theory of human knowledge is suggested by HOOKER's "radical naturalist conception of cognition", a self-reflexive theory on the nature of understanding. He adopts the "phenotype extended analogical" model of EE to integrate it in his regulatory systems conception, which he calls the "embedded EE of science." Here evolution is viewed as a hierarchical process of the development of self-organizing complex adaptive systems, with human cognition as an "extension of both horizontal and vertical regulatory complexity across many orders and levels" (HOOKER 1995, p42). Cognition, in the broader sense of "intelligence"—which includes "marshaling feeling, volition, and evaluation (cognitive, moral, and aesthetic)" (HOOKER 1995, p12)—is described as the result of an interaction between species-specific cognitive and cultural evolution and individual psychological development. Both processes are integrated within a larger framework of regulatory self-organization as an extension of physical phylogeny and ontogeny.

A current revolutionary shift in scientific understanding of systems dynamics from reversible and decomposable to nonlinear and irreducible models of action represents the actual historical context of HOOKER's reconstruction of rationality and epistemology in terms of adaptive and self-organizing, autonomous processes. This reconceptualization of knowledge and reason replaces the formal modeling as a simple logical computing machine deriving from the analytic philosophy tradition, AI, and the cognitivist paradigm in psychology, with a model of cognitive agency that allows to embed individual goal-pursuing behavior as well as collective decision making processes in its particular context. The aim is to "allow the explicit introduction of problem context to cognitive theory and so an explicit role for *social* structure, in particular a central role for the institutionalized social structure of science in scientific rationality" (HOOKER 1995, p4).

HOOKER's point of departure are some key ideas on cognitive dynamics which are already provided, to different degrees, by the 'rationalist' EEs of POPPER, RESCHER, and PIAGET, viz. that like every adaptive process, epistemic progress should be linked to both an external, wide-ranged competence of correspondence with the environment *and* internal autonomy and self-organization in terms of the preservation of coherent operations within the system, regardless of external changes.[37] The steps on the way to a fully naturalist regulatory systems theory are a thorough reconstruction from minority fragments of POPPER, (ii) a serious renovation of RESCHER's theory, and (iii) a simple "stripping and polishing" of PIAGET's account of knowledge (HOOKER 1995, pp10–11).

Hooker's dynamical framework does not claim that there is a primitive analogy between phylogeny and ontogeny, or between scientific evolution and cognitive development. Nor does it simply equate evolution with knowledge and vice versa (the equivalence postulate of Altenberg EE). Rather, HOOKER constructs a interactive four-mapping model of *processes*—instead of product states—comprising (1) the "homomorphic" interaction between phylogenetic and ontogenetic processes, and (2) the relationship of different processes of information incorporation, expressed by the cognitive realm as a regulatory extension of the organic domain (HOOKER 1995, pp243f).[38]

The main ingredients of the regulatory systems account are (a) the clear analysis of the hierarchical nature of regulatory systems in which the conception of a population as a system with the individuals as their sub-systems replaces the old set/member distinction, and (b) the reconciliation of functional and causal explanations as different representations of the same phenomena. Their completely naturalistic, regulatory systems analysis requires the combination of all four kinds of description in a complementary fashion, both at the organic and the cognitive level. (c) Objectivity as achieved in science is modeled as a general capacity of regulatory systems to maintain stability and restore invariance, a process of *homeostasis*. (d) The achievement of scientific progress can be described in systems-dynamical terms as the increase of regulatory order and, hence, of the system's flexibility with respect to its response to stimuli: *homeorhesis*. Science works by the application of objective knowledge, improves its results in content and methodology, and is *adaptable*. The last idea (e) reformulates science as a social regulatory system in which the complex internal organization, provided by the social, institutional structure, supports the cognitive dynamics by limiting and enhancing them.

Situated activity and interactive emergence. HENDRIKS-JANSEN (1996) offers a most promising approach to the naturalization of mental phenomena by the grounding of animal and human behavior in its evolutionary and individual history. His focus on behavior is a response to the impossibility for cognitive science and cognitive psychology to construct satisfactory models of psychological processes by means of computational programs.[39] HENDRIKS-JANSEN points to two basic shortcomings of these approaches: On the one hand, natural classes of psychological traits cannot be inferred from functional classifications of formal task description based on design criteria[40] but only from genetic or historical explanations of actual behavior patterns. On the other, intentional behavior, instead of requiring a pre-existing internal representation, can be seen as an emergent product of the interaction between an individual and its intentional environment.

This analysis is based on two more or less explicit presuppositions. First, a naturalization of human intelligence should be grounded in evolutionary theory. A fully evolutionary explanation, however, must include the complex processes of the life cycle which mediates between an abstract Mendelian genetic level and the level of natural selection. Here HENDRIKS-JANSEN seems to "share a commitment to this view of development as interactive emergence over time"[41], and follows recent strategies in evolutionary theory to ground adaptive claims

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in their phylogenetic context (GODFREY-SMITH 1994, 1996; GRIFFITHS 1995).

With his notions of "situated activity", "interactive emergence", and "history of use", he captures a threefold emergent process: "[Species-typical activity patterns] emerge in a species as a result of natural selection, in a maturing individual as the result of ontogeny, and every time they occur within the life of that individual as the result of interactions between the creature's low-level activities and its species-typical environment" (HENDRIKS-JANSEN, p248).

The bulk of this fascinating book is devoted to a long argument against the *cognitive paradigm* with its "intentional stance" (DENNETT 1987) and information processing models of the mind, to an analysis of research strategies provided by ethology and situated robotics, and to a sketch of HENDRIKS-JANSEN's own approach. Culture, language, and interactive contexts "scaffold" a creature's intentional behavior (the situated combination of some species-typical behavior patterns) through its "bootstrapping" in a world of meaning—viz. our cultural standards of practice with nature and artifacts, social interactions, and other extended projects—which is itself the product of interactive construction and negotiation. As an attempt to construct a scientific backbone to the contemporary cultural-psychological *contextual paradigm* with its microanalytic methods, HENDRIKS-JANSEN distills promising methodological strategies from autonomous agent research and from an evolutionary based ethology sensu LORENZ.

The main ingredients of his approach are (1) the adoption of a rigorous historical explanatory strategy in terms of MILLIKAN's "history of use" (which can be usefully studied in situated robots) to isolate the appropriate natural kinds of species-typical behavior patterns; (2) the inclusion of development and learning to study the *interactive emergence* and *cultural scaffolding* of the creature's behavior, and (3) an alternative view on *intentionality* as "aboutness", as a property of human thought and behavior which is individually learned and socially scaffolded by an interactive, cultural and linguistic (hence: meaningful) environment.

This completes our survey of some of the new approaches of the evolution of cognition which EE could ponder.

Notes

1 Philosophical naturalism as we understand it is contingently grounded in evolutionary theory (section 4, EN5). A non-evolutionary naturalism, although logically conceivable, would be an inopportune and untimely option given the current state of the sciences. Note that this is not the same as claiming that non-DARWINIAN alternatives are out of the question (BARHAM 1990).

2 Until quite recently, "hereditary" was almost universally understood to be synonymous with "genetically inherited/inheritable" in this context (but see WIMSATT 1986)—a restriction we will reject below (section 3, EE7).

3 The first program has been alternatively called *phylogenetic epistemology* (OESER 1997, following LORENZ), EE_1 ("EE der ersten Stufe") (OESER 1987), *EEM* (BRADIE 1986), *EE* (VOLLMER 1987), *bioepistemology* (HAHLWEG/HOOKER 1989), *natural–scientific* or *empirical EE* (DELPOS 1996), or *cognitive EE* (MAYR 1997); the second program has been referred to as EE_2 ("EE der ersten Stufe") (OESER), *EET* (BRADIE), *evolutionary philosophy of science* (VOLLMER), *philosophical EE* ("wissenschaftstheoretisch bzw. geisteswissenschaftlich ausgerichtete EE") (DELPOS), or *DARWINIAN EE* (Mayr). Problems with and refinements of this conventional distinction are discussed in HOOKER (1989, p101–110; 1995, p36–42), whose analysis we endorse for the major part but cannot discuss at this occasion (cf. CALLEBAUT/STOTZ 1999a). We will henceforth refer to the first program as EE_1 and to the second as EE_2 as a matter of sheer convenience, without necessarily endorsing all of OESER's views on the matter.

4 LORENZ is often seen as the great pioneer of EE_1, whereas POPPER is often given the chief credit for EE_2 (e.g., OESER 1988; HAHLWEG/HOOKER 1989a; ENGELS 1989). But as POPPER's student BARTLEY (1976, p468) notes, POPPER, who "had not previously put the problem [of the evolution of knowledge] in so full a context [as CAMPBELL did]", reached "a new level of abstraction as a result of his interchange with CAMPBELL—and also from his encounter with some related work by Konrad LORENZ to which CAMPBELL drew his attention." More important from our point of view, POPPER's rather analogical if not metaphorical EE arguably was not very naturalistic (BRADIE 1989; CALLEBAUT 1995a; CALLEBAUT/STOTZ 1999b). A case can also be made for considering Jean PIAGET as a co-founder of EE, both because of his admirably consistent naturalism and focus on epigenesis (CALLEBAUT/PINXTEN 1987; HAHLWEG/HOOKER 1989; HOOKER 1994, 1995).

5 A recent vintage: NAGEL (1986, pp78–81), VAN FRAASSEN (1989, pp143–145, p360), PÖLTNER (1993), JANICH (1996, pp135–153) or MUES (1997).

6 A succinct but quite adequate characterization of the "new DARWINISM" may be found in the June 25, 1993 issue of the *Times Higher Education Supplement* at the occasion of the conference on "Evolution and the Human Sciences" held at the London School of Economics, London, 24–26 June 1993.

7 See section 4, EN1 and EN3. Non-testability is one reason why POPPER'S EE does not qualify as a naturalistic theory in our sense: His methods level is exempted from the evolutionary dynamics he posits at the level of theories. (His

falsifiability principle, by the way, was meant to be analytic not synthetic, and hence cannot be reflexively applied to itself).

8 The 'Anglo-American vs. Continental philosophy' distinction is used for brevity's sake here; it is obviously too coarse-grained to be of much use. A more specific question of philosophical geography concerns the existence of a genuinely "Austrian Philosophy" emphasizing "psychology, language, science, analysis and empiricism" and thereby distinct from "the tradition of KANT, HEGEL and HEIDEGGER in Germany characterized by metaphysical extravagance" (LEHRER/MAREK 1997, p.ix), as proposed by Rudolf HALLER. If Haller is right, Altenberg EE, to the extent that it takes its credentials from KANT would be a German rather than an Austrian philosophy!

9 But as a member of the Altenberg Circle remarks himself, almost nostalgically, these days are over: "… das, was heutzutage unter der Bezeichnung EE läuft, ist ein ziemlich breitgetretener und von der philosophischen Kritik breitgeklopter erkenntnistheoretischer Komplex von Aussagen, der abgesehen von zum Teil überzogenen und nicht eingelösten Ansprüchen in sich mehr und mehr widersprüchlich geworden ist und sich von den ursprünglichen Intentionen … weit entfernt hat" (OESER 1995, p270). The context of this observation is a discussion of Ludwig BOLTZMANN's EE. OESER also questions the value of an epistemology that can endorse methodological conceptions as different as BOLTZMANN's mechanicism and the phenomenalism of that other pioneer of EE, BOLTZMANN's rival Ernst MACH: "Welchen Wert hat eine Erkenntnistheorie, die zu so unterschiedlichen methodologischen Auffassungen in der physikalischen Forschung führt?" (OESER 1995, p271).

10 We have reviewed some of these ideas in CALLEBAUT (1995a) and CALLEBAUT/STOTZ (1997).

11 Cf. the massive impact of popularizers of DARWINIAN evolution such as DAWKINS, DENNETT, or GOULD. WEINDLING (1990), among others, has shown how 19th-century *DARWINISMUS* in Germany functioned as *Religionsersatz*, venerating nature as a healing and restorative force that was all by itself capable to improve the quality of human lives. It could be a fascinating topic for contemporary historians or sociologists of science to investigate how the cautionary moral sermons of today's biologists function culturally and ideologically.

12 The main organizational locus of this collaboration is the International Society for the History, Philosophy, and Social Studies of Biology (ISHPSSB).

13 Even the neo-DARWINIAN hardliner George C. WILLIAMS (1992, pp3f) has come to accept, following Stephen Jay GOULD, *historicity* ("the recognition of the role of historical contingency in determining properties of the Earth's biota") as one of the three "doctrinal bases" of "successful biological research in this century", along with *mechanism* and *natural selection*.

14 In the sense of 'resulting in a local optimum'—see CALLEBAUT (1998a, p85, n21). Note, however. that evolution is not a rational designer, at least not if rationality is conceived in terms of optimization: "Optimal solutions in evolutionary terms might be difficult to recognize as efficient solutions in design terms. Natural selection often hijacks organs or patterns of behavior that originally emerged for a quite different 'purpose'" (HENDRIKS-JANSEN 1996, p7; cf. EE7). This is one among several reasons to prefer a 'bounded rationality' approach to evolutionary matters (cf. section 4, EN4).

15 *Vicariance* is the ability of a system to 'shortcut' evolution by using inductively achieved knowledge to anticipate environmental features it can react to. These intrasystemic processes are based on the same mechanism of variation, selection, and retention (VSR) as the external adaptation process. On this view knowledge is brought about exculisvely by the VCR process (see also DENETT 1991, pp199–208). Cf. DAWKINS (1993) on the internal "virtual world" in which animals live, and which may become a part of their environment "of comparable importance to the climate, vegetation, predators and so on outside." DAWKINS envisages a "hardware-software co-evolution" along these terms.

16 Following BRENTANO, mental phenomena are defined by their *intentionality* in the sense that they refer to something outside the system ('aboutness') , or *represent* a thing 'out there'. It would seems that the 'operational closure' warranted by cognitive systems is able to transform information into a specific kind of meta-stable structures which do not only allow for the acquisition of further information but also *represent* the source of the information in a certain way (compare and contrast DRETSKE 1981, 1988; MILLIKAN 1984; GODFREY-SMITH 1986).

17 "Over immense periods of time the intellect produced nothing but errors. A few of these proved to be useful and helped to preserve the species: those who hit upon or inherited these had better luck in their struggle for themselves and their progeny." (NIETZSCHE, *The Gay Science*, 110, quoted in THOMSON 1995, p165).

18 HOOKER (1987, p262) extends this line of thinking to the way evolutionary naturalism deals with science itself: "The rationalist and empiricist are both dogmatic, they are already certain about the nature and sources of knowledge… The conventionalist and more radically the sceptic are 'morons' about cognition, they reject the significance of questions concerning alternative goals for science, alternative methods for achieving those goals and the like. Both groups agree in dismissing cognitive evolution at the philosophical (meta-scientific) level. The naturalist realist, by contrast, insists on theorizing philosophy of science as a fallible theory of science, thus unifying cognitive theory."

19 The evolutionary psychologists TOOBY/COSMIDES (1992, p36) list the following dualisms that persist in both science and the wider culture: "rationalism versus empiricism, heredity versus environment, instinct versus learning, nature versus nurture, human univerals versus cultural relativism, human nature versus human culture, innate behavior versus acquired behavior, CHOMSKY versus PIAGET, biological determinism versus social determinism, essentialism versus social construction, modularity versus domain-generality…"

20 HORGAN's (1997) vision of "the end of science" relies heavily on STENT's views. BARROW's (1998) claim that the mark of a mature science is that it predicts the boundaries of its domain, rejoins the theme of reflexivity (self-reference) dear to naturalists (section 4, EN3).

21 His own brand of scientific realism, BUNGE maintains, combines what he takes to be the "sound halves" of the two great epistemological traditions: conceptual analysis, theorizing, proof, and discussion, on the one hand, and observation, measurement, experiment, and praxis, on the other.

22 Cf. also CZIKO's 1995, ch. 16, arguments against the "innatist" construals of selection by PIATTELLI-PALMARINI and GAZZANIGA.

23 In RUSE's (1986. 1989) version of EE, which is inspired by sociobiology, "epigenetic rules" à la LUMSDEN/WILSON (1981) correspond to the biologically reinterpreted KANTIAN forms and categories of the Altenberg program.

24 D. S. WILSON (1990, p41) concurs: "As David HULL (pers. comm.) has remarked, it often seems that the primary goal of the EEM program is to use evolution as a substitute for God, as the agent that endows humans with the ability to know, without seeking any additional detail." Cf. CAMPBELL in CALLEBAUT (1993, pp294f on "passing the justificatory buck to evolution."

25 But for the naturalist, this moral assurance is but an instance of wishful thinking!

26 Convinced that there exists an essential tension between biological and social evolution (CAMPBELL 1997; for an assessment see CAPORAEL 1997), CAMPBELL (1975a, p1120)—writing in the heyday of anti-authoritarian education—was concerned that "psychologists almost invariably side with self-gratification over traditional restraint", and that "there is in psychology today a general background assumption that the human impulses provided by biological evolution are right and optimal, both individually and socially, and that repressive or inhibitory moral traditions are wrong…" Granting that on some specific issues, careful study under the enlarged scientific perspective that comes from the joint consideration of population genetics and social system evolution "will leave us convinced that the world (ecology, selective system) has changed in ways that make the traditional moral norms wrong", he recommended nevertheless that "as an initial approach we assume an underlying wisdom in the recipes for living which tradition has supplied us with." Cf. CAMPBELL (1975b, p99), writing about the fear the message "agression is natural" elicits in his "fellow peace-oriented liberals": "LORENZ does not want to provide the semblance of scientific support for these [agressive] traditions. Quite the contrary. Yet it unfortunately remains true in the present climate that labeling agression as 'natural' may well have the effect of labeling it 'normal' and 'good'. Perhaps we should educate ourselves away from this oversimplified, overoptimistic morality, back toward that distrust of human nature found in our religious traditions."

27 LORENZ responsed to CAMPBELL in CAMPBELL (1975b).

28 In an attempt to define laws of nature as necessarily true of any world of the same natural kind as our world (but not logically true), BIGELOW/ELLIS/LIERSE (1992) define our world as "one of a kind", viz. "as a member of a natural kind whether or not there are any others of its kind."

29 Thus HARDCASTLE (1995, p173) on the question how we can develop a scientific theory of consciousness if we can't develop a plausible third person account of it: "We seem forced to the conclusion that the phenomen[on] of consciousness has no place in materialist theories of the mind. But, as I have maintained throughout, the solution to this difficulty is to realize that our commitment to materialism is more than any intuitions we have about what conscious experience is or is like." Notice that not all naturalists are so keen on being materialists (cf. section 4, EN1).

30 Although we think that our usage of the term 'metalearning' is appropriate in this very context, it should not mislead the reader to think that naturalistic theories of science presuppose a 'levels view' of science that dismisses cognitive evolution at the 'philosophical' level (cf. the HOOKER quote in note 18). In principle, any naturalistic/scientific account of science must be reflexive, otherwise one will 'get out of the system'. Although he would have some qualms for being put in the naturalistic camp, Henri ATLAN's (1986) "acrobatic reason" is an apt description of what is at stake here: "une raison acrobatique et sans filet qui ne peut plus se prévaloir d'un métadiscours, d'une métathéorie (méta-physique, méta-biologique, méta-psychologique ou autre)".

31 "Over the last century or so, advances in scientific understanding have taken us to the point where the possibility of a science of knowledge is something that we can now think seriously about; the study and understanding of knowledge, a knowledge of knowledge, is no longer just the province of philosophy" (PLOTKIN 1992, p1).

32 HOLZKAMP-OSTERKAMP (1989, p242), for one, thinks the analogies between EE and dialectical and historical materialism are so unmistakable that "whole passages from the writings on EE read like dialectical materialism in 'conspirative terminology'" (cf. SCHLEMM 1997).

33 "On my view, the jury is still out on the question of whether successful science can be constructed using intentional categories. But it is working scientists constructing theories and gathering data who will resolve this question, not philosophers of the puritan persuasion. If there is good science to be made out of intentional categories, that's all the legitimation they need. And if an account of 'naturalizing' rules against intentional properties (or any other sort of property) invoked in successful science, then it is the account that is defective, not the intentional properties." (STICH 1996, p199)

34 "By separating out the notion of action-specific energy from goal directedness, LORENZ made it possible to conceptualize the energy as something that merely drives or pushes. It is thus no longer a matter of the energy's striving toward a goal; it is more a matter of the animal's being animated by a particular type of energy to engage in a particular type of activity that will tend to bring it face to face with the sign stimulus required to release the FAP, which constitutes its natural goal. This makes the energy involved seem far less mysterious [than in MCDOUGALL's view]. To the minds of the early ethologists, it closely resembled the notion of potential energy used in the physical sciences. Lorenz devised his famous cistern model to show that there was nothing mystical or unscientific about action-specific energy.…"

35 On certain construals (e.g., Roy BHASKAR's or Richard BOYD's), naturalism and transcendentalism *are* compatible (CALLEBAUT 1993, p2 n. 3).

36 Cf. CAPEK (1968, p188) on the "biologically oriented theory of knowledge" BERGSON, MACH, and POINCARÉ had in common. "But both MACH and POINCARÉ, like SPENCER and HELMHOLTZ, *but unlike BERGSON*, were convinced that the process of adjustment of the human cognitive functions was basically completed and that, minor modifications apart, no basic revision of the 19th-century picture of reality would be required."

37 A stance taken to save some basic ideas of normativity within HOOKER's radical naturalism; cf. HOOKER (1999).

38 CHRISTENSEN/HOOKER (1997) present a richer discussion of this theme.

39 These models formalize intentional behavior in terms of task description, whereas intentionality, which is traditionally regarded as the main characteristic of mental phenomena, enters the model as a functional role, derived from a design analysis and implemented in the agent's head.

40 Context-free calculations presuppose a direct problem-solution relationship, so that a well-defined problem leads to the functions and tasks necessary to achieve this. An adaptationist uses the same principles of reverse engineering and functional generalization.

41 This is described by OYAMA (1999) as a basic similarity of different approaches more or less loosely united under the label Developmental Systems View (DST), which she did initiate.

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Alexander Riegler

"The End of Science": Can We Overcome Cognitive Limitations?

Abstract

"Why is the universe knowable?" DAVIES (1990) wonders. In this paper, I argue that science is not a matter of knowing any universe. Rather, it is a—as history has shown—superior method of guidelines of how to organize experiences yielding predictive power. Historically, two types of models have given rise to the effectiveness of science, narrative and mathematical models. Based on cognitive psychological investigations, I point out that due to the human nature of scientific reasoning both types of models are limited. With the advent of computational devices scientific investigation may now be extended to "externalized deductions", which are not subject to a limited short-term memory and slow performance. To shift this to computational science we have to recognize that models in all three approaches have basically the same function. Although this might not solve the realist's question of how models relate to the world (at a deep philosophical sense), it will guarantee the continued existence of contemporary science beyond the cognitive barrier.

Key words

Philosophy of science, cognition, complexity, models, reality, constructivism, problem solving, artifacts.

EVOLUTIONARY EPISTEMOLOGY has brought forth the idea of science as an evolutionary system (cf. CAMPBELL 1974, OESER 1984, RIEDL 1983). From systems theory of evolution (RIEDL 1977) and the theory of punctuated equilibrium (GOULD/ELDREDGE 1977) we know that evolution does not proceed homogeneously. Rather, periods of stasis are interrupted by dramatic changes. Over the last few centuries we have experienced science as a dynamic enterprise with several revolutions. Will we now face the stasis of science? These arguments are not purely theoretical: In a recent book, John HORGAN explicitly speaks of "The End of Science" (1996). In this paper, I outline the mechanisms of the "evolution of science" by first finding an appropriate perspective on the philosophy of science. Then, after a short review (and rejection) of HORGAN's thesis, I identify three core problems to science. These problems, which are mainly motivated by cognitive psychology, have become serious since science started to deal with complexity. Computer models have been proposed to cope with this latest frontier of science. However, such models have not received acceptance among the scientific community due to the presumingly arbitrary relationship between computational model and "the reality out there" (the reminiscence syndrome). I argue that this must be true for any model, including narrative and mathematical models. The success of models is their predicative power. I conclude that due to cognitive limits of human scientists, model-building is also subject to limitations. By using computational devices, those limitations might be transcended.

Different perspectives on scientific activity

Ralph GOMORY (1995) argues that the choice of appropriate perspectives is significant if we want to make the unknown visible: "[I]n distinguishing the known or the unknown from the unknowable, the level of detail can be decisive" (p88).

This is also true if we look at philosophy of science: to find the "proper" explanation which both explains success and failure of science. Unlike many other papers on the present topic (e.g., LAUDAN 1977, STENT 1978, VAN FRAASSEN 1980, NERSESSIAN 1987, FAUST 1984, GIERE 1993), I will not focus on yet another philosophical treatment. Rather, I will deal with the subject of science in a pragmatic way which aims at the success of predictions. The following list locates this position among all possible views on the philosophy of science. Furthermore, the list summarizes what we potentially can expect from a philosophy of mind. For the rest of the paper, I will, triggered by recent discussions about the end of science, outline why we should concern ourselves with a possible limitation to science at all and what a possible solution might look like.[1]

We must clearly outline what a philosophy of science should do for us:

1. Is it a pure philosophical exercise where arguments of various authors are compared, thus building a discourse which does not necessarily "ground" (HARNAD 1990) in the subject (i.e., scientific activity)? However, the ultimate goal of any scientific inquiry is not to be an end in itself. Rather, it has a constructive character in that it allows us to extend the set of actions which we use in order to predict and perceive our world in an increasingly better way.
2. Is it descriptive in order to explain what has happened to date? Any description may be based on sociological models (cf. KUHN 1962), on a psychological approach (cf. GIERE 1993), or even on a computational philosophy of science (cf. THAGARD 1988).
3. Is it a normative instrument which tells scientists how to do science, such as the research methodology of the logical positivists (SCHILPP 1963) or Karl POPPER's rejection of induction (1934)?
4. Is it generative in that it is capable of predicting what the future of science will be? Can we expect that the principal limits of science can be specified analogously to GÖDEL's Incompleteness Theorem, which poses limits on formal systems (e.g., CASTI 1996a)? Following an entirely positivist view on science, can we even expect the end of science since "all great revolutions are already behind us" as proposed by the recent *The End of Science* book by John HORGAN (1996)?
5. Or will it provide insights and mechanisms which—in the long run—can be automatized and therefore passed over to artificial artifacts which then will carry out scientific reasoning? Such proposals have been around for many decades already, cf. the General Problem Solver of NEWELL and SIMON (1972) and BACON of LANGLEY et al. (1987) More pragmatically, one may think of the usage of computers in mathematics as the first sign of this development. For example, the famed four-color conjecture (APPEL/HAKEN 1977), which demonstrated that problems may no longer be tackled by traditional, human-based methods. It made use of the power of hundreds of hours of computation on supercomputers in order to calculate individual cases rather than to prove the problem in a traditional mathematical way.

The last two items especially may yield the expectation that in future, when the content of scientific theories will have transcended the limitation of the human mind, computers (or other artifacts) may take over the business of exploring Nature.

What can such computers "learn" from human scientific activities, and what does "Nature" refer to? Are there limits to science carried out by humans? If we don't face any such limits, we barely need any artificial extensions. Too much "pleasure" is involved in the process of generating scientific knowledge. But, as with transportation, walking also may provide much pleasure, nevertheless society would not be able to survive without motorized means of transportation. This is a good demonstration of human nature: Although we have been using motor-based vehicles for many decades, we still, and in fact more than ever, enjoy our biological movement, not to mention that our health depends on it. To draw an analogy, in the future scientific reasoning might be done by machines, nevertheless we will still enjoy the intellectual challenge by tackling problems which we can grasp with our (narrow) mind. In the following chapter, I will present these restrictions in more detail, starting from the positivist's fear that the big parts of the scientific pie have already been eaten, leaving only crumbs for contemporary (and future) scientists.

The end of science?

I was recently reminded of the possibility that science might come to an end by the provocative book of John HORGAN (1996) with the self-explaining title *The End of Science*. "The great scientists want, above all, to discover truth about nature", John HORGAN wrote in his 1996 book. And since "researchers already mapped out physical reality", all that is left is to fill in details[2]. To be more concrete, "all" refers to good science, which is capable of producing "surprises", i.e., scientific revolutions as has been introduced by DARWIN, EINSTEIN and WATSON & CRICK. However, "all" neither refers to the (boring?) scientific activities of filling in all the gaps within the map mentioned above, nor to applied science. And it does not refer to what HORGAN calls "ironic science", those efforts of physicists and chaos-complexity-researchers ("chaoplexologists" in HORGAN's terminology, p192) which argue for the existence of high dimensional superstrings and life inside computers.

HORGAN dissociate himself from any relativist view on science brought forth to a large audience by

Thomas KUHN (1962) in the early 60s[3]. He therefore cannot help but think that all present scientific knowledge is the complete framework to describe and cope with reality. Taking a KUHNIAN perspective into account, he might rather—possibly correctly—speak of an end of the *current paradigm*.[4] Indeed, as Melanie MITCHELL (1995) in her response to HORGAN's previously published paper "From Complexity to Perplexity" (1995, p1) pointed out, that "[t]he specter of the "end of science" periodically appears in the scientific and popular literature, often at the end of one scientific era (e.g., NEWTONIAN mechanics), before the beginning of a new one (e.g., quantum mechanics)."

According to her and other "chaoplexologists", the specialization in science "has certainly produced great advances, but the problem of complex systems demands approaches that span disciplines". In other words, the current set of paradigms needs to be substituted by another set. Now, will there really soon be a change of paradigm in the traditional KUHNIAN sense?

Certainly we have to take evolutionary constraints into account. This is the line of argumentation which, for example, is followed by Colin MCGINN (1994). Like rats and monkeys which cannot conceive of quantum mechanics, humans may be unable to understand certain aspects which are more sophisticated than our current theories in science. MCGINN primarily addresses the problem of consciousness. He emphasizes that for humans to grasp how subjective experience arises from matter might be like "slugs trying to do FREUDIAN psychoanalysis—they just don't have the conceptual equipment."

These issues make it clear that I am mainly interested in what we can learn from philosophy of science and how we can apply this knowledge to artificial systems in order to transcend the limits of human mind. As mentioned above, due to the ever incomplete aspects of psychology and sociology, any further philosophical treatise will not make further progress. An analogy makes it clear: Since we are not able to build such sophisticated systems like birds, we focus on technical realizations based upon what we have learned about aerodynamics. Our airplanes might have reached a level of enormous complexity (ARTHUR 1993), yet they are not as elegant in their movement as birds. However, planes outperform natural solutions in speed and payload. Likewise, we will construct artifacts that carry out science probably less aesthetically but more efficiently.[5]

Certainly, no theory can ever reach the status of universal applicability. This is also true for any theory that wants to explain the dynamics of scientific activity. Rather, it seems useful to explain science to an extent which will allow us to formalize its key mechanisms and to transfer it to artifacts.

What could the problems be?

The problems which may cause a decay of progress in human science are rooted in its members: the human scientists and their cognitive apparatus. In a nutshell, as human beings in general, and as scientists in particular we all suffer from essentially three problems that limit our cognitive capabilities (RIEGLER 1994):

1. We are used to thinking in *paradigms* in the sense of KUHN (1962)[6]. Indoctrinated at school and university, paradigms speed things up. They enable us to forget about previous steps in our scientific investigation and thus about the need to exhaustively search the entire problem space[7] which is enormously large for scientific investigations. The bad side of this is that this shortcut also limits our way of thinking and problem solving.
2. The limitation of our short-term memory does not allow us to compare more than seven knowledge items at the same time (the well-known *chunks* of MILLER 1956). This even further restricts our capability to entirely step through all corners of nontrivial-sized problem spaces of which scientific issues consist.
3. Faced with the limitations of our thinking and the fact that interesting phenomena are complex by nature, we have to ask: Which items must we choose in order to prune the cognitive search tree[8] effectively? In other words, how shall we solve the problem of *relevance* or the *frame problem* as it is called in artificial intelligence. Daniel DENNETT (1984) illustrates it with the following analogy which will serve as a reference throughout this paper: A robot, R1, as well as its improved descendents, have to learn that its spare battery, its precious energy supply, is locked in a room with a time bomb set to go off soon. To solve this problem the robot has to develop plans in order to foresee effects of its actions. It fails because it does not pay attention to the implications of its planned actions. Taking possible side-effects into account, however, does not help. As the real world is very complex, an exhaustive list of all side-effects would take too long to take any action in real-time. Hence, the robot must know how to

distinguish between relevant and irrelevant side-effects. But even this process of discrimination needs an enormous amount of computation, all the more as each of the possible effects must be assigned with some (quantitative) credit in order to evaluate their usefulness.

All three items are subject to closer investigation in the following sections.

Limiting canalization through paradigms

Science is carried out by human beings whose work is constrained by the current set of scientific methods, the well-known KUHNIAN paradigm. KUHN (1962) describes the relationship between a scientist and his or her paradigm as follows: "Scientists work from models acquired through education and through subsequent exposure to the literature often without quite knowing or needing to know what characteristics have given these models the status of community paradigms." (p46)

Such continuous repetitions of one and the same methodical schema inevitably confine the future scientist's capability of problem-solving. More than 30 years before KUHN, José ORTEGA Y GASSET (1929/1994) described the apparently automatic techniques for problem-solving already quite straight forwardly. He points out that scientists work with available methods like a machine. To achieve a wealth of results it is not even necessary to have a clear concept about their meaning and their foundations. This way, the average savant contributes to the progress of science as he is locked into his lab. ORTEGA compares this situation with that of a bee in its hive and the situation of a donkey in its whim-gin.[9]

Similar to KUHN's notion of paradigm, Paul FEYERABEND (1975) outlined the concept of stereotypical research schemata. He localized their roots in the cognitive development starting in early childhood: "From our very early days we learn to react to situations with the appropriate responses, linguistic or otherwise. The teaching procedures both *shape* the 'appearance', or 'phenomenon', and establish a firm *connection* with words, so that finally the phenomena seem to speak for themselves…" (p72)

FEYERABEND argues that starting in our early childhood we are acquiesced in an education that very clearly outlines both the way we have to view the world and the way we have to act in the world. Alternatives are suppressed or referred to the realm of fantasy. That is how our concept of reality emerges.

The purpose of paradigms, very much like the notion of reality (DIETTRICH 1995), is to secure acquired scientific knowledge and to provide a base for further developments. Historically, the scholastic age is a typical example of where the lack of a true hierarchical organization of concepts and paradigms finally led to its disintegration. Quite obviously, knowledge can only be acquired incrementally step by step without being exposed to the risk of starting from scratch over and over again. Of course, as pointed out by Rupert RIEDL (1977) for the realm of genetics, such hierarchies of interdependent components on the one hand increase the speed of development by magnitudes. On the other hand, they are "burdens" with respect to their canalizing effect since established structures define the boundary conditions for their future evolution. Exactly the same applies to science: In order to achieve progress we have to establish a firm ground of paradigms through education. Each time a new disciplines with a different set of paradigms rises, it has to start from scratch and is thus prone to a weak explanatory performance in terms of details, as the new discipline of complexity research demonstrates.

The psychology of science

Quite clearly, we can find limitations of deductive reasoning, a key component within the scientific method. Human brains are obviously not indefatigable automata capable of storing practically unlimited amounts of temporary information as is demonstrated by the well-studied problem of the Towers of Hanoi (SIMON 1975): The number of subgoals which have to be simultaneously remembered correlates to the number of disks. This means that the subgoals have to be stored in short-term memory which, as already pointed out by the famous work of MILLER (1956), is quite limited. People fail to solve the problem for towers with more than three disks if they are not allowed to use paper and pencil. Therefore, it is not surprising that for systems that consist of a large number of variables we use computer models.

In psychology, an enormous amount of literature deals with the problem solving capacity in human beings. In the following I will present some them which quite clearly show that our cognitive capabilities for problem solving (or *puzzle solving* in a more KUHNIAN terminology) are not only limited but also prone to errors when it comes to investigating complex systems.

"Stack overflow "

In the contemporary design of computers, a component called the stack stores temporal information necessary to evaluate mathematical functions. This is similar to the carry when adding large numbers by hand; we also must not drop it in order to obtain the correct result. Since computers are finite implementations of TURING's infinite machine, the stack is finite, too. This can easily be demonstrated by trying to evaluate an infinitely recursive function, i.e., a function which takes its results as arguments over and over again. Depending on the speed and stack size of the computer, a "stack overflow" error will occur within a few milliseconds, indicating that the stack can no longer memorize all sub-results. The stack in humans, also referred to as short-term memory, does not need to be exposed to infinitely recursive problems in order to show the same behavior.

The example of the mutilated checkerboard (WICKELGREN 1974) is one such case. It asks whether it is possible to arrange 31 domino pieces on a checkerboard on which two diagonally opposite corner squares have been cut off (yielding a 62 squares board). According to the author, it is almost impossible for a naive test person to find a quick solution. Obviously, the number of squares is correct (2 times 31 yields 62) but the human mind is incapable of managing the arrangement of black and red squares on a two-dimensional area. However, the problem becomes "trivial" if one simply counts the number of black and red squares on the mutilated checkerboard which differs by two, whereas on the 31 domino pieces the number of imaged black and red squares is equal. Gestalt psychology argues that we are good at recognizing regularities in pattern, e.g., patterns that consist of black and red areas. But an exact analysis of possible arrangements requires the temporary storage of subresults which transcends the capacity of our short-term memory.

"It ain't broke so don't fix it"

In our everyday life, things are used in a particular context, e.g., we use a hammer to drive nails into a wall, matches to light a fire. In fact, things do not seem to exist "outside" their domains of functionality[10]. DUNCKER (1935/45) posed the task to support a candle on a door. The available items were matches and a box filled with tacks. Since the test subjects considered the box as a mere container they failed to empty it and to tack it to the door where it could serve as a support for the candle. In general, our thinking is canalized (or fixed) with respect to the way we have learned to deal with things. Since cognitive development deals with both concrete and abstract entities, we assume that this restriction also applies to abstract concepts which prevail in scientific, especially mathematical reasoning.

The water-jug problem, studied by LUCHINS (1942), provides empirical data for this assumption of "mechanization of thoughts". He asked test subjects to measure out a specific quantity of water using a set of three jugs with known volume. The first two problems LUCHINS posed could be solved by applying a certain sequence of pouring water from one jug into another. Test subjects had no problems to discover this procedure. Quite the contrary. They got used to it and tried to apply it to further tasks. Like the adage says, "It ain't broke so don't fix it". What the test subjects overlooked was that much simpler procedures would have led to the same result, simply because their inductively working mind was set to the previously successful strategy.

The consequences of these psychological experiments (among others) are clear. During academic education we are subject to courses and seminars in which we acquire a certain way of thinking, a paradigm in the KUHNIAN sense. Recalling the problem of DENNETT's robot, the advantage of such canalizations is clear: thinking can be abbreviated (and thus accelerated) by dropping computations about implications which are already known. This way, entire branches of our internal search tree can be pruned, thus leaving more time to concentrate on the unknown part.

The general view of human problem solving

KUHN (1962) argued that reasoning within normal science was puzzle-solving, i.e., it is concerned with solving tricky problems. From a general point of view, reasoning is a back-and-forth walk within the problem space, with several decision points. We might find that a particular branch does not yield the desired result, therefore we have to return to a previous decision point and try an alternative branch. Unfortunately, by a priori cutting off parts of the search tree through functional fixedness we are simply blind to those alternative branches and hence unable to find the solution to a particular problem. Rather, as LUCHINS' *Einstellungseffekt* experiment demonstrates, we prefer to stick to inductive solutions, very much like the turkey in

Bertrand RUSSEL's analogy (after CHALMERS 1982): It started to believe in the charity of its owner—since the latter fed him regularly—before it ended up as Christmas meal.

As we have seen, for certain problems our cognitive limits are quite narrow. In the following, I will first relate these limits to concepts of Evolutionary Epistemology (thus providing some ideas how these limits have been come about). Then I will show that the gap between these limits and the complexity of systems we might consider to be "fancy calculator games", i.e., the computational approach to science, is much bigger than one might assume.

Ratiomorphic apparatus

According to the LORENZIAN Evolutionary Epistemology, human beings feature a system of innate forms of ideations which allows the anticipation of space, time, comparability, causality, finality, and a form of subjective probability or propensity (RIEDL et al. 1992). This ratiomorphic apparatus has to be distinguished from our rational abilities (LORENZ 1973/77, RIEDL et al. 1992) since the former indicates that "…although this ideation is closely analogous to rational behavior in both formal and functional respects, it has nothing to do with conscious reason."

Each of these ideations can be described as *innate hypotheses* (RIEDL 1981/84). These inborn teaching mechanisms are mental adaptations to basic phenomena that enable organisms to cope with them. One of these mechanisms—the ability for detection or discrimination of foreseeable and unforeseeable events—serves as a foundation for all others. This hypothesis of the *apparent truth* (*Hypothese vom anscheinend Wahren*) guides the propensity of a creature to make predictions with different degrees of confidence, ranging from complete uncertainty to firm certainty. Therefore, it produces prejudices in advance or anticipations of phenomena to come. The capability to anticipate is necessary for survival and contributes to the success of every higher organism.

The probability with which an unconditional stimulus follows a conditioned one correlates with the reliability of the response of the organism linking the two. The consequence is that animals and human beings behave as if the confirmation of an expectation makes the same anticipation more certain in the future. This is also the case in science where repeated confirmation of an expectation leads to certainty.

Equipped with this innate set of hypotheses, can we successfully face problems which are by far more complex then those of ancient man? ROSS ASHBY in one of his last publications (1973) maintained "…that the scientist who deals with a complex interactive system must be prepared to give up trying to 'understand' it." In order to evaluate this statement let us have a closer look at the concept of complexity.

Complexity in science

In his remarks on constraints on science, Thomas HOMER-DIXON (1995) points out that human cognitive limits are due to the lack of infinite ability to understand and manage the complex, multivariate processes of ecological and social systems. The relationships in some of these systems are simply too numerous and complex to be grasped, much less controlled, by the human intellect.

What is complexity, and how does it relate to the human mind? KOHLEN/POLLAK (1983) characterize the "cognitive enterprise" as follows: "Cognitive science has worked under the general assumption that complex behaviors arise from complex computational processes. Computation lends us a rich vocabulary for describing and explaining cognitive behavior in many disciplines, including linguistics, psychology, and artificial intelligence. It also provides a novel method for evaluating models by comparing the underlying generative capacity of the model." (p253)

They conclude their analysis of complexity with: "[T]he computational complexity class cannot be an intrinsic property of a physical system: it emerges from the interaction of system state dynamics and measurement as established by an observer." (p264)

As pointed out by several authors (GRASSBERGER 1986, WALDROP 1992, HEYLIGHEN/AERTS 1998), complexity is hard to define. Rather than trying yet another definition, I will outline the inherent difficulties in understanding systems which entail a non-trivial amount of interdependent components. Where does this non-triviality start? VON FOERSTER (1985, 1990) provides a useful definition of the potential complexity of algorithms when he distinguishes trivial from non-trivial machines.

A *trivial machine* is a machine whose operations are not influenced by previous operations. It can be described by an operator (or function) p which maps any input variable x to an output variable y according to a transition table: $p(x) \rightarrow y$. For such machines the *problem of identification*, i.e., deducing the structure of the machine from its behavior, can be solved, since they are analytically determinable, independent from previous operations, and predictable.

On the contrary, *non-trivial machines*, i.e., TURING-like devices, consist of a memory holding an internal state z and two operators:

1. The "effect" function p_Z realizes the state dependent mapping: $p_Z(x) \rightarrow y$
2. The "state" function p_X performs the state transition within the non-trivial machine: $p_X(z) \rightarrow z'$

The important issue here is that the identification problem is not longer solvable even with very small non-trivial machines. Consider a machine with two states, four inputs, and four outputs. The number of possible models that potentially implements such a relatively simple system is: $4^4 \cdot 4^4 = 2^{16}$. A similar machine with three instead of two internal states requires 2^{24} models. And if the number of internal states, in- and outputs is not known to the experimenter, there are some 10^{155} possible models of that machine. And this number is *transcomputable* in the following sense: Hans BREMERMANN (1962) claimed that "[n]o data processing system, whether artificial or living, can process more than $2 \cdot 10^{47}$ bits per second per gram of its mass".[11]

Even if we consider the entire Earth in its over 4 billion years of existence as a computer, no more than 10^{93} bits could have been processed, the so-called *BREMERMANN's limit*.

These dimensions make it clear that one should not underestimate the complexity of systems with even simple structures. In artificial life, BRAITENBERG's (1984) famous vehicles perfectly illustrate this phenomenon that complex and hard-to-analyze behavior can be generated by simple rules. It also confirms the view that biological cognitive apparatus are not necessarily more complex than artificial ones.

Using the concept of BRAITENBERG bricks in a more abstract way, we may claim that the perceived world consists of numerous such entities which mutually interact without knowing the internal organization of each other. Let's think of a society where living and non-living entities form a web of interdependencies. Such a web must be maintained and controlled in one way or the other. Among others, POPPER (1961) advocated the idea of piecemeal social engineering, namely the idea to utilize science as a tool for political reform. The following example shows that such a program piecemeal engineering is hopelessly inadequate.

Complex Problem Solving—An Example

Years before "SimCity" became a popular game, Diettrich DÖRNER used simulation to scientifically investigate the problem of social and economic engineering. DÖRNER et al. (1983) created "Lohhausen", a computational simulation of a small city. Its economic situation is determined by the city-owned clock company, by a bank, shops, practices of physicians, and so on. 24 female and 24 male test subjects have to take the office of the city's mayor for a total of 120 (simulated) months. Since the clock company is publicly owned, the mayor is able to massively influence the economy of the city. Due to a large variety of parameters, like the freedom to arbitrarily set the level of tax, the test subjects had more freedom than in a real situations (DÖRNER 1989, FUNKE 1986). To measure the effectiveness of the virtual mayor, a set of parameters was defined, such as the "satisfaction" (i.e., the weighted sum of single aspects of living comfort) and size of the population, the financial situation of city, company productivity (in terms of sales and back orders), the income of the bank, the average standard of living, the number of unemployed and homeless people, the use of energy, etc.

In summary, Lohhausen pointed out several weak points of human problem solvers who face complex systems. It's interesting to note that these "flaws" are similar to those of the robots in DENNETT's illustration of the frame problem. The test subjects were likely to fail because they did not carefully analyze the current situation. Rather, they referred to a kind of "intuitive" interpretation of the state. They also tended to neglect side-effects and future long-term impacts. The test subjects thus treated the complex net of interdependencies among variables as simple linear accumulation of facts. Even worse, the virtual mayors tended to focus on a single core variable which then became the starting point for a long chain of causal connections. Such strategies reduce cognitive efforts and allow the outline of a clearly defined goal which is inevitably linked to the improvement of that core variable. They provide the illusion that the system is controllable and make it easy to forget feedback mechanisms.

Lohhausen was not only a prototype for a new type of experiment within cognitive psychology. It was also a pleading against the analytic method of traditional analytic science. The investigation of highly interconnected components of a complex system—and sciences are increasingly face such systems—by selecting a few variables is insufficient, but this is all what human problem solvers can do.

Many scientists, especially positivists, may reject the significance of such simulated worlds. Rather, they emphasize that our scientific knowledge comes exclusively from Nature, which a fancy simulation program will never be able to represent. This perspective is true to the extent that indeed the relationship between a simulation and the "natural" phenomenon with which it is associated remains unclear. However, the crucial point is: What is the "nature" of Nature? How can one claim that there is a fundamental gap between the qualities of a simulation and the qualities of Nature. In other words, where does the knowledge in (natural) sciences come from?

Where does scientific Information and knowledge come from?

In his otherwise quite comprehensive treatise on science, Atlee JACKSON (1995, 1996) pointed out that there are solely three different approaches to scientific information:

- Physical observations
- Mathematical models
- Computational explorations

By proposing this list, JACKSON seems to confuse apples with pears. Humberto MATURANA (1978) very clearly outlines the steps of the traditional scientific methods. He distinguishes four cyclic steps:

1. Observation of a phenomenon that, henceforth, is taken as a problem to be explained.
2. Proposition of an explanatory hypothesis in the form of a deterministic system that can generate a phenomenon isomorphic with the one observed (or internal model, as will be outlined in the next section).
3. Proposition of a computed state or process in the system specified by the hypothesis as a predicted phenomenon to be observed.
4. Observation of the predicted phenomenon.

Hence, physical observations refer to the process of gathering data in order to build up an internal model. They are not a model themselves and thus are not a source of information. Observations without a model do not make sense. Rather, they are necessary for a model to fit the "facts".

In addition, JACKSON missed another source of information: Scientific literature. As already pointed out in the previous section, only if we are able to "atomize" a chapter of scientific discovery into a single "fact", can we build up a hierarchical knowledge system. This is in fact the great strength of the scientific method: It first requires one to investigate the observed phenomena and then to make the results available to others. In this sense I speak of "atomization", of condensing the results of often several years of research into chunks upon which further research can be carried out without the necessity to repeat the previous experiments.

Furthermore, JACKSON's use of language is misleading for several reasons

- It suggests that only physical models are observations, i.e., they have an exclusive option on discovering "reality".
- Only through a formal mathematical approach we can establish scientific models.
- Computation may be another source but it plays the role of a scout who explores the unknown before civilization, i.e., mathematics and physics, dare moving in to this area.

JACKSON makes this fundamental distinction explicit when he notes that these source are fundamentally different. For the following reason this distinction is more of an obstacle than helpful. Computer models are just as good as mathematical models. Any formal logical-mathematical model can be fully mapped onto a computational system. This equivalency is basically what TURING showed in 1936. Both the mathematical and the computational approach are capable of serving as a model. The only difference is that they use different notations and therefore different deductive mechanisms.

Despite this fundamental equivalence, computational models are not fully accepted as information sources. Critics of the computational philosophy of science movement disqualify such models as fancy calculators (GLYMOUR 1993). HORGAN (1995, 1996) even calls such approaches "ironic science" which has no practical use. Either mathematical and computational models both are valid instruments for science or neither of them. It all depends on what we expect the role of a model to be.

What is the very nature of a model in general?

John HOLLAND et al. (1986) and Brian ARTHUR (1994) outline the importance of models as temporary internal constructs. They are constructs in that we build them inside our minds on the basis of experience. They are temporary since they are exposed to continuous modifications. This pragmatic model concept can be outlined (and extended) as follows:

1. In order to cope with an (apparently) complex problem we create a model. Such a model may for example consist of schemata (in the psychological sense), i.e., if–then rules. This is the root of scientific abstraction: we subsume a certain contextual configuration in the if part of such a schema and associate it with an expectation or action on the right side, the then part. It is important to note that in general neither guidelines are given of how to choose the appropriate level of abstraction nor what expectations or actions to associate with a particular if.
2. We have seen that the human mind is subject to several serious restrictions, such as the problem of correct deductions in large systems, e.g., when ruling a city as the example of Lohhausen has shown. We are simply unable to concurrently focus on more than one chain of inference. Fortunately, one feature of our internal models is that it allows for simple deductions as compared to its model, the "real world"
3. As a next step we act upon the result of these deductions.
4. If our actions are successful and our expectations associated with the then part are fulfilled we are likely to keep our mental model and think of it as a "representation of the world". Otherwise, we may modify the set of rules, add new rules in order to cover new contexts, or delete obsolete rules or those which have been proven false (in the sense of Popper).

In other words: "[W]e use simple models to fill the gaps in our understanding … This type of [inductive] behavior… enables us to deal with complication: we construct plausible, simpler models that we can cope with." (ARTHUR 1994, p407)

This characterization of models not only resembles the notion of scientific hypothesis, it also clearly states that any act of thinking is based on such models. Some of them might be quite simple, others more sophisticated with regard to the number of schemata involved. As a consequence, not only scientific knowledge is formulated this way, but also our "knowledge about the world". Ultimately, this leads to the picture that when comparing a mathematical or computational model with Nature, we in fact compare two models with each other: the mathematical/computational one with our Nature model we have been constructing all our life. The roots of the latter can be found in our childhood. Since this period is no longer accessible by introspective reflection, we tend to assign an objective ontology to our well-developed model of Nature (cf. VON GLASERSFELD 1987).

Due to this relativist (or constructivist) position models are what Erwin SCHRÖDINGER (1961/64) originally assigned to metaphysics: scaffolds for our thinking, and, consequently, scaffolds of the scientific building.

Models as scaffolds of thinking

From a psychological point of view, there is no difference between scientific and nonscientific thinking. "Scientific Thinking… depends on the same general cognitive process which underlie nonscientific thinking" (FREEDMAN 1997, p3) Therefore, one should expect that our mind in general works like the scientific method commands.

Indeed, SJÖLANDER (1995) proposes an alternative perspective on thinking. In his view, mind actually generates hypotheses in order to make sense of perception. As long as the internal hypothesis is able to let perceptions fit in, we will keep that hypothesis rather than thinking of alternatives[12]. Despite the simple structure of such internal models, they sufficiently abstract from the perceived "real world" in the sense that they allow for successful anticipations. Thus, phrases in oral speech like "I want to draw your attention to…" are obviously referring to the fact that we need to build a "good" internal model if we want to understand another person. In other words, we need the opportunity to build (implicit) anticipations about what is to come[13]. SJÖLANDER illustrates this with an example from biology: A dog hunting a hare "…does not need a full picture of a recognizable hare all the time to conduct a successful hunt. It is able to proceed anyway, guided by glimpses of parts of the hare, by movements in vegetation, by sounds, by smell, etc. If the hare disappears behind a bush or in a ditch the dog can predict the future location of the hare by anticipating where it is going to turn up next time, basing this prediction on the direction and the speed the hare had when seen last." (p2)

The need of internal models upon which we can draw conclusions (the "innere Probierbühne" with the words of SJÖLANDER) becomes even more clear if we investigate the "world" of people who have a reduced spectrum of perception, e.g., blind people. Oliver SACKS (1995) describes the case of man, Virgil, who had been blind since early childhood. At the age of fifty his eye sight was restored. Contrary to the general expectation, this was no help for Virgil since the way he has been living as a blind person was incompatible with the way normal sighted people perceive and organize their world view. With effort and practice, he was able to interpret some of the visual data in terms of the world as he had known it through his other senses, but he has immense difficulty in learning these interpretations. For instance, visually he cannot tell his dog from his cat. For him, due to the lack of visual impressions, the temporal aspect of his world had priority. He recognized things by feeling their surface in a particular order. He didn't get lost in his own apartment because he knew that after entering there was furniture in a particular sequence which he perceived in a temporal order. To put it differently, he was living in world of anticipation. A particular cupboard was followed by a table, so once he reached the cupboard he anticipated reaching the table with the next step.

Having this relativist but nevertheless powerful concept of models in mind we may now turn to a final view on the relationship between models and "reality".

Models and "reality"

HORGAN (1995) quotes Jack COWAN, according to whom "chaoplexologists" suffer from the reminiscence syndrome: "They say, 'Look, isn't this reminiscent of a biological or physical phenomenon!' They jump in right away as if it's a decent model for the phenomenon, and usually of course it's just got some accidental features that make it look like something." (p74)

This syndrome resembles the old philosophical conundrum of how to know that a model of a natural system and the system itself bear any relation to each other. How can a deductive operating system, such as mathematics, allow for building bridges and flying to the moon?[14]

First, it is useless to speak of "the system itself" because we cannot make statements about that system outside the framework of science without violating the scientific imperatives. But describing the system with the methods of science is exactly what we want to do. We thus cannot anticipate the result of our inquiry (cf. VON GLASERSFELD 1987).

Second, what we actually do by building a model is to install a second source of information, namely the model itself. Originally, we wanted to investigate the observed system but due to its complexity and/or hidden features we are neither able to sufficiently explain the historical behavior nor to anticipate the future behavior. Thus we build a simplified analogy which we hope exhibits similar or identical behavior. In order to gain maximum security we apply our set of scientific methods. Of course, this is only relative security, as POPPER already pointed out several decades ago: he argued against the idea that the inductive principle of verification could ever lead to secure knowledge. He was, however, not aware that his falsification imperative cannot yield a secure knowledge either. One can never be sure whether he or she actually included all explanatory components that show that a theory is definitely wrong (cf. the example in LAKATOS 1970). DENNETT's example, well-known in the artificial intelligence community, demonstrates that any effort to determine all relevant factors is a non-practical enterprise. We need not even to refer to GÖDEL's Incompleteness Theorem to find scientific reasoning restricted within the vast complexity of combinatorics. It is appropriate to state that from an epistemological point of view such a situation is highly unsatisfying. On the contrary, we—like the robot in DENNETT's example—cannot spend almost endless time on building science by taking all possible (borderline) cases into consideration. Fortunately, from a pragmatic perspective, the scientific method—mainly based on the reproducibility of experiments—enables to build sufficiently reliable models and artifacts.

Before I investigate the limits of internal models, I first want to provide arguments as to why narrative descriptions in natural language can be considered as models, in order to underline the basic claim of fundamental equivalence of all sources of scientific knowledge.

Models in natural language

In a nutshell, natural language may serve as a basis for internal models in the above sense, since

- language is constructed by humans;
- one can carry out deductions from statements without being "grounded" (in the sense of HARNAD 1990);
- the correspondence to the "real" world is arbitrary (from a general (i.e., population) point of view; for individuals, it has communal character).

A theory merely formulated in everyday language may also serve as a model for science. In contrast to a formal mathematical or computational model it has neither clearly defined entities nor clear rules. Referring to VARELA (1990, p95), where the author compares the crystal-clear world of chess with the world of a car-driver, a scientific model built in natural language is potentially more complex than a formal model: states and rules are ambiguous and thus cannot be easily handled by the human mind. (Cf. the psychological findings on the performance of humans for Tower of Hanoi). In addition, the distinction between natural language models and mathematical models mirrors the superiority of the scientific method over an everyday explanatory approach since it makes use of crystal-clear and therefore more "debuggable" (in the sense of falsifiable) structures.

A prominent problem in philosophy addresses the issue of genuine no-go areas (STEWART 1997): One can propose scientific questions which are not solvable. Examples are time travel, the intention to go north of the North Pole while staying on the surface of the Earth, speaking about the time before Big Bang (which originated time), and perhaps the current search for a General Unified Theory. At first glance, these are questions about something that obviously does not exist. But within the framework I outlined so far such questions are examples of the very nature of language as a model. Again, no statement in natural language actually describes something. Rather, it is a model to which we seek correspondence in the set of phenomena we perceive. As has already been acknowledged by many linguists (e.g., LENNEBERG et al. 1967), language is a very powerful mechanism in that it can create patterns of arbitrary length and recursivity. Therefore, any natural language model (as well as questions that arises from such models) can be arbitrarily long and recursive. The only constraints arise in the process of synchronization within a community, e.g., a scientific community where a certain set of questions is simply ignored.

The arbitrary correspondence to a "real" world is also the place where the "symbol grounding" problem (HARNAD 1990) is located. It arises from the fact that formal computations (according to the Physical Symbol System Hypothesis of NEWELL/SIMON 1972) are the manipulation of symbols devoid of meaning. In his paper, HARNAD asks: "How can the semantic interpretation of a formal symbol system be made intrinsic to the system, rather than just parasitic on the meanings in our heads? … The problem is analogous to trying to learn Chinese from a Chinese/Chinese dictionary alone." (p335)

From a realist point of view it would be desirable for symbols to indeed have a semantic content. It is true that the realist position distinguishes between computational tokens, which may be meaningless symbols, and the representation per se.[15] But as FRANKLIN (1995) notes, things do not come labeled. This constructivist statement is indeed the crucial point: Symbols receive their meaning through projection of an observer, through his or her interpretation.

This instrumentalist point of view emphasizes the notion of a knowledge that fits observations, or, as VON GLASERSFELD (1990) puts it, "It is knowledge that human reason derives from experience. It does not represent a picture of the real world but provides structure and organization to experience". Searching the correspondence between an internal model and the world which is experienced as the "outside world" is like the relationship between a key and a lock. Many keys open a lock. VON GLASERSFELD (1984) speaks of the crucial distinction between *match* and *fit*: The fact that we can open a lock with a key does not tell us anything about the structure of the lock. It merely shows that the key is viable. In the same sense we can interpret physical observations.

Where do these interpretations originate? In the above argumentative framework, the notion of reality and knowledge are subject to relativism. But how can an individual get to know these ideas of an absolute truth? In accordance with Ernst VON GLASERSFELD (1982, p629), the process can be outlined as follows: First, the active individual organizes his or her sensorimotor experiences by way of building action schemata. Only those schemata are maintained which yield an equilibrium or help to defend it against perturbations. Second, these operational structures are abstracted from the sensorimotor "content" which originally gave rise to their creation. Consequently, they are ascribed to things and thus "externalized". Continuously viable ascriptions yield a belief in their independent existence and henceforth a belief in an objective truth. In other words, the individual established an internal model upon which he or she can carry out deductions "in an atmosphere of security" since such deductions strictly follow a logical–mathematical calculus.

Limitations of model-building are the limits of human sciences

Whatever approach we choose—the natural language model, the formal-mathematical or the computational model—we end up with a simplification in our mind. We draw deductions and conclusions upon this abstraction. Then we seek to fit (in the sense of VON GLASERSFELD) the results with the "outer world". In the case of natural language models, these deductions are traditional views of discourse, which require rhetoric abilities. In the case of mathematical models, we find the

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classical tools of strictly defined logical rules. Finally, in computational models, we externalize deductions in the sense that we compute them in artifacts rather than in our own brains. Is this already a first sign of future developments where more and more parts of scientific reasoning will be shifted to automata? Gain for speed may only be one advantage of this "takeover". The other advantage is the possibility to overcome the shortcomings of deduction (as shown in the case of Lohhausen and the Towers of Hanoi).

Fortunately, to give an outlook of the computational science as anticipated in this paper, making use of models can be formulated algorithmically (cf. HOLLAND et al. 1996 and RIEGLER 1997 for examples). Since the pragmatic perspective of science also does not provide mapping-rules between a model and the experienced reality, such scientific machines may gain true intellectual independence. This means that in contrast to artificial intelligence programs whose input is fed by humans and whose computational output is interpreted by humans, scientifically reasoning devices will develop their own interpretation of perceived data.

Conclusion

The recent *End of Science* affair triggered by John HORGAN reminds us that we have to seriously think about the possibility that the *progress* in *human* science will decay and finally arrive at a *cognitive* barrier. In contrast to HORGAN's romantic view of science, according to which we have to seek for *The Truth*, the matter of science is not the reality. Rather, it consists of fairly sophisticated scaffolds which both permit predictions and create meanings.

In their analysis of the limits to scientific knowledge, philosophers tend to forget that science is carried out by human beings who are anything but infallible machines. Hence, it pays to look at the cognitive limits rather than at the theoretical limits of disciplines such as the applicability of GÖDEL's Theorem to physics and to the philosophy of mind. Like it is impossible to build infinitely high scaffolds, we cannot manage infinitely large cognitive scaffolds. The conclusion of an end of *human* science thus neither repeats previous we-already-know-everything arguments nor forgets the merits of what we have achieved so far. And, fortunately, it gives hope that a possible *trans*-science, carried out by computational devices, will at least preserve the powerful feature of predicting.

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Notes

1 Since philosophy of science can potentially be an endless discourse of arguments referring recursively to each other, I will apply OCCAM's Razor in order to not get lost in a "jungle" of arguments in favor of concentrating on the essential issues. However, when it becomes necessary, I will refer to more details, such as findings from psychology.

2 Horgan earned many critics, among whom are ANGIER (1996), CASTI (1996a, 1996b), HAYES (1996), MITCHELL (1995), SILBER (1996), and STEWART (1997)

3 His main argument is the apparent paradoxical situation in which he fancies such perspectives, i.e., the self-applicability of a meta-science. "Is falsificationism falsifiable?", he asked Karl POPPER in one of the numerous interviews which make up his book.

4 But this, of course, does not sound as dramatic as the title he actually chose.

5 Relating Pierre TEILHARD DE CHARDIN's (1966) concept of "Noosphere" to the present World Wide Web is certainly of historical and philosophical interest in that it demonstrates that the idea of a global net is certainly not a product of the most recent decades. Nevertheless, a mere discussion of the possibility of such a net does not create the net. But now since it is existent we can prove earlier predictions of former thinkers.

6 As already pointed out by several authors before me (most prominently by MASTERMAN 1978), KUHN did not provide a strict definition of a paradigm. I do not think that such a definition is possible, since it would require exhaustively including psychological and sociological aspects of individuals. I therefore would like to define a paradigm as the *implicitly* known set of standard procedures of how to perceive and investigate a problem. Since perception is selective, problems may stay invisible.

7 By "problem space" I refer to the n-dimensional abstract space set up by the n variables that characterize a problem. Most likely, not all these variables are visible within a current paradigm. Therefore, the current paradigm is a subspace (with lower dimensionality) of the entire problem space. Problem solving is moving in the problem space by varying one or more variables concurrently.

8 The notion of a search tree refers to the graph in the n-dimensional search space whose knots are the decision points.

9 Wolfgang STEGMÜLLER (1971) finds even harder words for this dogmatism. He writes that we should feel sorry for the average scientist since he or she is a uncritical, narrow-minded dogmatist who wants to educated students in the same way.

10 This psychological finding resembles the philosophy of Martin HEIDEGGER. See DREYFUS (1991) for an overview.

11 Bremermann calculated this number by evaluating the maximum possible energy content within a gram of mass.

12 Cf. also the example of the mermaid by von Glasersfeld 1983, p54: Somebody changes the subjective interpretation of an expression only if some context forces him or her to do so.

13 In my functional model of a cognitive apparatus (1997) I take advantage of this "constructivist-anticipatory" principle: Behavior of cognitive creatures is controlled by schemata which, once invoked, ask for sensory or internal data *only* when they need them. In other words, the algorithm neglects environmental events *except* for the demands of the current action pattern. The algorithm leads to a significant decrease in performance costs since the simulation algorithm need not provide the full environmental information to the agent at every time step. This is in contrast to the information-processing paradigm that defines the cognitive system as a bottleneck. The essential features must be selected among the wealth of "information" is provided by the "outside" in order to decrease the enormous amount of complexity.

14 For the relationship between mathematics and physics in particular see, for example, Wigner (1960).

15 The hope of the artificial intelligence community is therefore that a formal model containing meaningless computational tokens need not necessarily imply a meaningless representation of the system.

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Nancy E. Aiken

Human Cardiovascular Response to the Eye Spot Threat Stimulus

Abstract

Since unconditioned response to eye spots is widespread among many animal species, it is of interest to determine if human beings, too, have evolved such a response to eye spots. Such a finding would affect our understanding of our cognitive processes, and generally affect our established view of human beings as completely volitional creatures since reflexive response to such stimuli would indicate that some decision making is biologically constrained. Fifty adults were tested for their cardiovascular response to the eye spot pattern as opposed to other similar patterns. The measures were heart rate, relative blood pressure and finger pulse volume. The subjects were grouped by culture, sex, and response-type. All subjects responded in a similar way to the eye spots compared to control patterns regardless of culture, sex, or response-type. The conclusion is that human beings respond differentially to the eye spot pattern just as do many other species and, therefore, may be somewhat more constrained by their own biology than was heretofore suspected. Moreover, the results may have implications for the study of aesthetic response.

Key words

Unconditioned response, cardiovascular response, eye spots, biologically relevant stimuli, aesthetic response, biologically constrained behavior, reflex, threat stimuli, heart rate, human.

Introduction

As products of evolution, we are creatures adapted to our environment. Predator–prey relationships are part of the environment for most animals, and *homo sapiens* is no exception. The glowing eyes of predatory beasts surely frightened our ancestors. Other animal species respond differentially to the eye spot pattern, which is assumed to represent contextually the eyes of predatory beasts (see COTT 1940, pp387–390). In fact, several species of animals have evolved an eye spot display which appears to serve as a means of scaring away predators who, themselves, are prey to other beasts. COTT (1940) describes eye spots as "terrifying masks" which serve to "bluff" enemies. BLEST (1957a and 1957b) demonstrated experimentally how passerine birds respond to eye spots. He placed dead mealworms on a box and allowed yellow buntings, chaffinches, and great tits to feed on them. Then, a bulb below the mealworms was illuminated revealing one of several patterns of circles, parallel lines, and crosses. The birds flew away from the pattern that most closely resembled the eyes of a vertebrate more often than they flew away from the other patterns. MARKS (1987) notes that the avoidance of eye spots is probably innate since birds reared in isolation also will exhibit this behavior.

Do human beings respond differentially to eye spot patterns? Have we maintained or retained an instinct so basic that it occurs commonly in other animal species? REDICAN (1975) suggests that a fixed and direct stare is a threat for primates intimating that we may not react to eye spots only because this response alerted our ancestors to the danger of being eaten, but also because eye spots act as social signals. COSS (1970) found that a group of 15 men and 15 women showed more pupillary dilation and brow movement, indicative of negative affective arousal, to slides of two horizontally placed circles compared to one circle or two or three diagonally or vertically placed circles.

Although we prefer to think that we human beings operate solely by our own will and our decisions are made consciously, uninfluenced by "base instinct," this is unlikely considering our knowledge of the affect of unconditioned reflexes, such as the defense response to the eye spot stimulus, on other animals. We freely acknowledge involuntary behaviors such as digestion and circulatory regulation and admit that normal locomotion involves little conscious decision making. Certain biologically relevant stimuli (such as predator eyes) would seem to offer further possibilities for reflexive action causing us to react without conscious decision making.

Although COSS (1965) tested human response to eye spots using pupil dilation as the measure, human cardiovascular response to eye spots has not been measured. Since cardiovascular response has been accepted as a measure of response to threat and has long been considered part of a defense response associated with fear (see CANNON 1929), results here add support to COSS' findings of human defensive response to the eye spot pattern. In this study three measures of cardiovascular response (heart rate, relative blood pressure, and finger pulse volume) are used to examine differences between cardiovascular response to an eye spot pattern and neutral patterns of circles.[1]

Explanation of Methodology

Unfortunately the exact nature of cardiovascular response to threat is not described with uniformity and agreement. Cardiovascular response to visual threat is especially in need of description. The expectation of the nature of the responses would be that heart rate would accelerate after a latent period with a peak at about 30 seconds post stimulus onset and finger pulse volume would decrease, again after a latent period with a peak at about 30 seconds post stimulus onset (TURPIN 1986). Relative blood pressure as measured by the plythesmograph has not been researched enough to offer a prediction of directional response, latent period, or peak. GRIBBIN/STEPTOE/SLIGHT (1976) did find, however, that blood pressure as measured by the plythesmograph does reliably follow blood pressure changes recorded by more conventional means.

TURPIN's (1986) expectations of the nature of cardiovascular response to threat result from experiments using auditory stimuli. His assessment of the research using cardiovascular measures in response to "affective visual stimuli" concluded that design factors in these experiments made the results unreliable. However, it is noteworthy that the results of these experiments using visual stimuli were not consistent with the findings of experiments using auditory stimuli (TURPIN 1986). The ability, then, to describe with some assurance the nature of cardiac responses to visual threat is much impaired. This situation made it impossible to predict what responses would be made in this experiment; therefore, the hypothesis adopted only asserts that the response to the presumed threat stimulus would be "different" from the mean of the responses to the presumed neutral stimuli.

Since the possibility of choosing neutral stimuli that might turn out to be not so neutral was considered to be relatively high, several presumably neutral stimuli were chosen. Responses to these "neutral" stimuli would be averaged in order to overcome the effects of any not-so-neutral stimuli in the group.

Research into not only the psychological literature but the ethological and neuroscience literature on the so-called orienting and defensive responses uncovered major differences in several areas: (1) nomenclature, i.e. what is an orienting response or a defensive response to a psychophysiologist may not be exactly the same thing to a behaviorist or a neuroscientist, (2) experimental design and data analysis are more different among these disciplines than within each of the separate disciplines, (3) theoretical viewpoint. These differences make synthesis on the orienting response and defensive response literature among these three disciplines impossible.

Although I felt that statistical analysis procedures used by psychology offered the best choice for analyzing the behavioral data, the protocol and parameters set by ethologists (see TINBERGEN 1948) for an experiment to test for an unconditioned stimulus offered the best opportunity for parsing out response to a presumed threat stimulus. Thus, this experiment is a hybrid of experimental viewpoint, design, method, and data analysis.

Although the rationale for each of these decisions is too lengthy to be included here (see AIKEN 1992 for a full discussion.), some discussion is necessary. My definition of a defense response is based on literature from all three above mentioned disciplines but primarily from my analysis of the ethological and neuroscience literature. Simply, a defense response is an adaptively appropriate behavior which has evolved as a complex reflex in, possibly, all animal species in response to a threat situation. In this study the specific definition is a particular cardiovascular response to the presumed threat stimulus. The exact nature of the cardiovascular response is difficult to predict (see the explanation above), but one could anticipate, minimally, an increase in heart rate. A full defense response includes many more behavioral responses such as sweating, piloerection, respiratory changes, etc. However, a full defense response would *not* be expected to a stimulus as innocuous as the presumed threat stimulus used in this study. The anticipated cardiovascular response would be in line with the relatively timid threat offered by eye spots to a human subject in a safe environment.

Neuroscience researchers have probably compiled the most literature on the defense response tracing its neural mechanisms in a variety of animal species. The goldfish's "C-Start" is an example (see the review by YOUNG 1989). Using mammals as subjects, CANNON (1929) identified physiological behaviors as being part of the defense response and suggested their tie to emotional behavior. Since then various researchers have attempted to define the precise nature of autonomic response to threat but the results have been conflicting. My study of these reports suggests that possible problems might include inadequate control and reporting of the exact nature of the stimulus situation and lack of consistency in collecting and analyzing data so that comparisons among studies may be made. A solution to part of these problems, I concluded, would be to use ethological methodology in controlling the stimulus situation since ethologists had historically been interested in and had devised the means of examining overt behaviors under threat by careful manipulation of the stimulus situation. Since these methods (see TINBERGEN 1948) are not all new to psychological methodology, it was not difficult to transfer them to a setting and to data collecting appropriate for a standard psychological experimental design and data analysis. The equipment, methodology, design, and analysis, then, were chosen because they offered the most sophisticated means available to me for a test of human response to eye spots.

When attempting to argue for the occurrence of a relatively inherent response, it is advantageous to compare disparate groups within the species. If all subgroups respond similarly, the case for a relatively innate behavior is strengthened. This study considers three subgroups within the human species. A comparison is made between the sexes. Also, a comparison is made between what many psychological studies have determined are different ways people respond to threat. That is, due to some as yet to be determined reason some people may not have cardiovascular responses to mild threat while some may respond with cardiac acceleration and others may respond with cardiac deceleration (See, e.g., BLOCK 1957 and ZUCKERMAN 1985). The third kind of subgroup is culturally based. Any study of human unconditioned response should address the issue of culture since it is assumed that much of human behavior is culturally based. If human beings respond to eye spots with differential cardiovascular activity and if this response is similar across cultures, then an argument for the unconditioned nature of the response is more easily supported. Thus, two diverse cultural groups are compared on the basis of their responses to the eye spots.

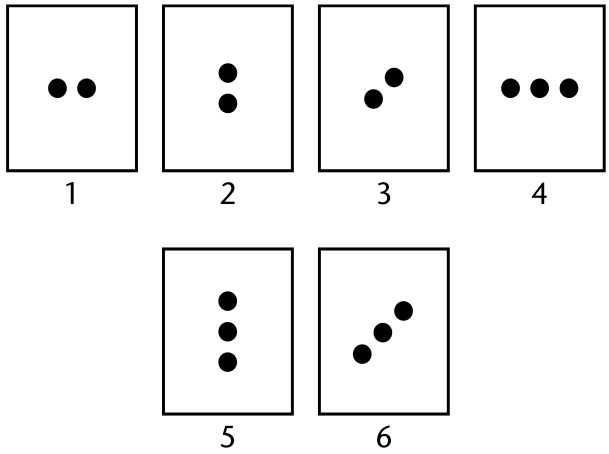

Figure 1: Stimulus slides used in this study. Slide 1 is the eye spot threat stimulus. Slides 2 through 6 are the controls. Adapted from COSS (1965), pp46–47.

Hypothesis

It is hypothesized that the eye spot pattern will elicit a significantly different cardiovascular response from the mean responses to the control patterns regardless of subgroup.

Methods

Subjects

The subjects were 50 volunteer American and Asian (mainland Chinese, Malaysian, and Taiwanese) adults. Their ages ranged from 18 to 43 years. There were 31 Americans, 15 males and 16 females, whose average age was 21 years and all of whom were white. There were 19 Asians, 9 males and 10 females, whose average age was 30 years and who averaged 2.1 years in the United States.

Measures

Three measures of cardiovascular response were taken: heart rate, relative blood pressure, and finger pulse volume.

Stimuli

The stimuli consisted of six black and white slides of various patterns of circles adapted from COSS (1965). Since neither a startle nor effects of response to novelty were desired, each sequence of test slides was preceded by one slide of the Roman Forum and the slides were shown to the subject prior to taking plethysmograph readings in order to reduce the possibilities of these confounds. The slides were numbered 1 through 6 and a random number table was used to organize them for each subject's viewing. Each slide was on screen for 10 seconds. The test stimuli are shown in Figure 1. The number one slide is the predicted threat stimuli; the other slides are control stimuli which were presumed to be neutral.

Equipment

The equipment used to measure cardiovascular response to the slides consisted of a Grass model 5 polygraph running at 2.5cm per second and a D.E. Hokanson, Inc. EC-4 plethysmograph with size 5cm and 6cm digital strain gages. Finger size determined which strain gage was used. A Kodak Carousel slide projector was used to project the images onto a portable screen. The projected image measured 19 1/2 inches by 29 inches, and the subjects' faces were 133 inches from the screen. The room was sound-proofed and temperature controlled. It could be darkened for adequate slide viewing. The subjects sat in an easy chair with wooden arm rests. Unfortunately the polygraph and the experimenter also had to be in the same room with the subjects, but the protocol used was designed to overcome any test anxiety this may have produced.

Design

This study used a split plot design with culture, sex, and response-type as between subject factors and slides and time as within subject factors. Thirty-one Americans were compared to 19 Asians. Twenty-four males were compared to 26 females. The WAVERAGE software program was used to group subjects according to the standard deviations of their patterns of response across time to all six slides. Time was divided into eight intervals, beginning with stimulus onset, with two seconds in each interval plus a four second base taken immediately preceding stimulus onset. Measures were computed for 16 seconds following onset of each slide. The length of the time period seemed prudent based on the findings of reviewers EVES/GRUZELIER (1984). (The TURPIN study of 1986 indicated the advantage of an even longer time period; however, the experiment was underway when TURPIN's study was read.) The dependent measures of heart rate, blood pressure, and finger pulse volume were all computed from the polygraph chart. The MANOVA computed contrasts based on multivariate statistics since the measures were taken over time.

Procedure

In order to control the stimulus situation, it is important that subjects be as relaxed as possible and that their attention is directed to the test stimuli. Base levels were established by waiting until the polygraph needle settled to the chart baseline before and after each slide was presented so that any change from base would indicate a reaction to the slide presented.

Scoring

Three measures were used as dependent variables: relative blood pressure, finger pulse volume, and heart rate. Relative blood pressure scores for each pulse were taken as the number of centimeters of pen deflection on the polygraph (either + or – from the zero base line on the chart), divided by the number of centimeters of plethysmograph calibration for the specific test. The calibration or length of pen deflection from zero on the polygraph chart varied between 22 and 26 cm. Raw scores were divided by the specific test calibration in order to obtain a ratio so that all scores would be equally weighted. Scores were quantified for the 4 second base preceding stimulus onset and for the 16 seconds after stimulus onset. The post stimulus seconds were divided into 2 second intervals as follows: 0–2 seconds, 2–4 seconds, 4–6 seconds, etc. Scores were averaged within the time intervals[2]. The base score was divided by 2 in order to weight it equally with the post-stimulus scores. Thus, each subject is represented by 9 relative blood pressure scores for each slide; the first score is the mean of the blood pressure scores within the base and the other 8 are the means for the post-stimulus time intervals in order. These 9 scores, therefore, represent a pattern of relative blood pressure response to each slide.

Finger pulse volume scores also represent a pattern of 9 scores for each slide for each subject. Each pulse on the polygraph chart within the 4 second base and the 16 seconds post stimulus was measured from peak to trough in centimeters. The means of the peak to trough scores were found for each time interval, and these scores represent the pattern of

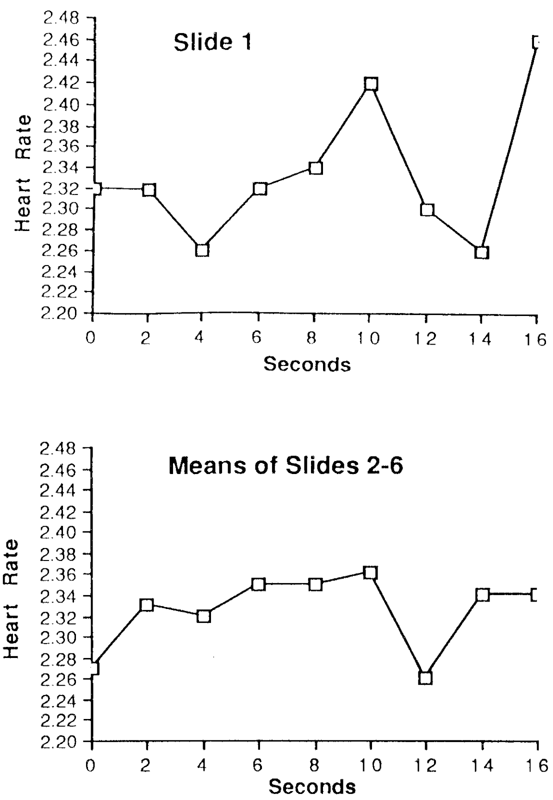

Figure 2: Means for heart rate response to slide 1 and the composite of slides 2–6 across time intervals.

finger pulse volume response to each slide for each subject.

Heart rate scoring was accomplished in a similar way. The pulses were counted for the base and for each post stimulus time interval. The base mean was computed in order to establish a pulse count comparable to the post stimulus time intervals. Thus, scores for each time interval were achieved representing a pattern of 9 heart rate scores for each slide for each subject. Note that heart rate scores can easily be converted into beats per minute by recalling that the score is a mean for a 2 second interval.

A MANOVA tested the contrast for the null hypothesis based on the pattern of response and tested for any interaction effects of culture and sex. The WAVERAGE software program grouped subjects by their blood pressure response (an arbitrary selection) to all 6 slides across time. Note that this grouping by response type procedure was used by HARE (1973) since autonomic responses appeared to break into categories of response types. This statistical analysis was the most appropriate to address the hypothesis.

Results

The MANOVA revealed no significant interaction effects for culture and/or for sex. Therefore, all subjects were collapsed across culture and sex for the response-type grouping.

Subjects were grouped using the WAVERAGE program for their response to all 6 slides. The 50 subjects broke into groups of 48, 1, and 1. Since the two subjects who did not fall into the largest group were well within chance, all 50 subjects could be treated as one group when inspecting the within subject results.

For the within subject results the MANOVA contrasted the pattern of response (the base mean and the 8 means of raw scores during succeeding two second time intervals for 16 seconds post stimulus onset) for slide 1 and the mean patterns of response to slides 2–6 for the three measures.

Heart Rate

The slide effect for heart rate for the response to slide 1 versus the mean of slides 2–6 was significant ($F = 27.85$, $df = 1/47$, $p < .001$). Figure 2 illustrates the pattern of response to slide 1 and the composite pattern of response to slides 2 through 6. Figure 3 illustrates the heart rate responses to each of the six slides.

Blood Pressure

The slide effect for relative blood pressure response to slide 1 versus slides 2–6 was not significant ($F = 2.70$, $df = 1/47$, $p < .11$). Figure 4 illustrates the pattern of response to slide 1 and the composite pattern of response to slides 2 through 6. Figure 5 shows the blood pressure responses to each of the six slides.

Finger Pulse Volume

The slide effect for finger pulse volume response to slide 1 versus slides 2–6 was significant ($F = 52.03$, $df = 1/47$, $p < .001$). Figure 6 illustrates the pattern of response to slide 1 and the composite pattern of response to slides 2 through 6. Figure 7 illustrates the finger pulse volume response to each of the six slides.

Discussion

The results support COSS' (1965) study which found greater pupil dilation to the eye spot pattern as opposed to other circular patterns. Here, 50 subjects

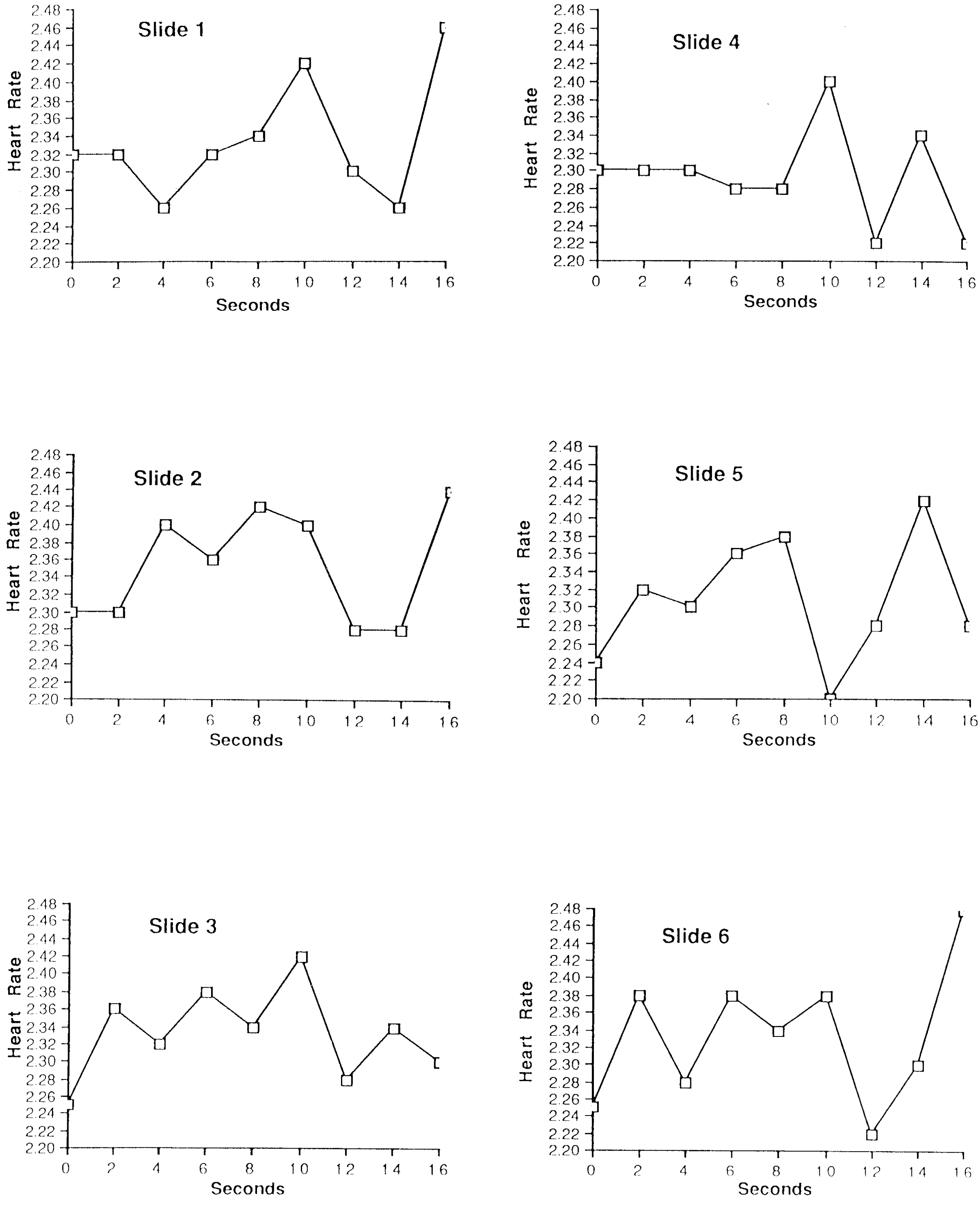

Figure 3: Heart rate responses to slides 1 through 6.

responded in similar ways to the eye spot pattern as opposed to other circular patterns as measured by heart rate and finger pulse volume. This test indicates that human beings respond to the eye spots differently than they do to other patterns of similar circular shapes.

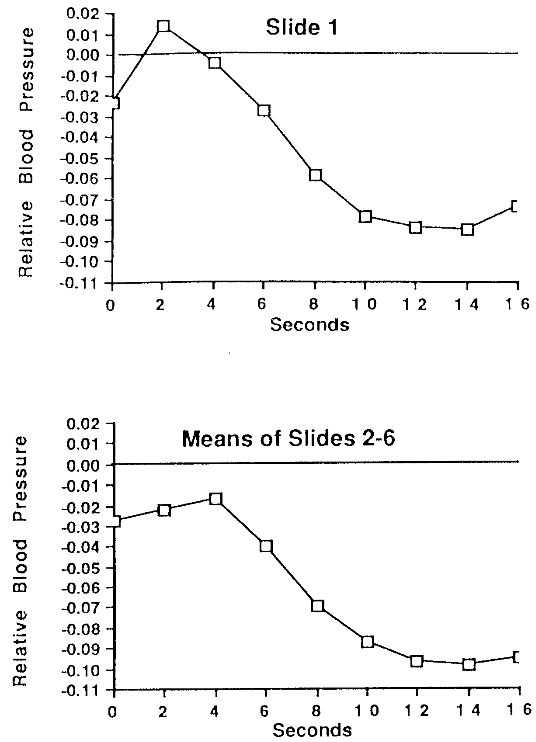

Figure 4: Means for relative blood pressure response to slide 1 and the composite of slides 2–6 across time intervals.

Heart Rate

Comparing the complicated heart rate response to the eye spot pattern (slide 1) as seen in Figure 2 to the heart rate responses to the control slides 2–6, it can be observed that the most obvious differences in the responses are: (1) the initial decrease, (2) the pronounced secondary increase, and (3) the final steep increase in heart rate response to slide 1. (Note that the entire pattern of response was compared by the MANOVA so that a second by second breakdown of response comparisons is not available.) TURPIN (1986) drew the conclusion that "unpleasant visual stimuli" evoke heart rate deceleration which appears to be the case with the early stages of this response. Note, however, that the response concludes with a steep increase in heart rate, which may be the actual defense response as indicated by EVES/GRUZELIER (1984) and TURPIN (1986). There seems to be no precedent for the presumedly innocuous control slides causing heart rate acceleration even though the acceleration is generally not pronounced. The expectation would have been that heart rate would decelerate in response to these control slides as it did at the 10 second mark, which may be the actual, anticipated orienting response as predicted by EVES/GRUZELIER (1984) and TURPIN (1986). This led to comparing the control slides to each other. Variability of response occurred within the control slides. Although no contrast produced a result at the .05 level, the contrast of slide 5 versus the mean of slides 2, 3, 4 & 6 gave these results: F = 3.77, df = 1/47, p < .06. Thus the neutrality of the control slides is somewhat suspicious. (Slide 5 does have context as a stop and go light which could account for what might be its not-so-neutral quality.)

Blood Pressure

The difference between slide 1 and slides 2–6 appears to be in the sharper, steeper immediate increase in blood pressure in the response to slide 1 which can be seen by comparing the response to slide 1 to the mean response to slides 2 through 6 in Figure 4. By the 4 second mark increases to all slides had peaked and were set to begin a substantial decrease which in turn peaked in each instance at the 14 second mark. Given this result relative blood pressure does not appear to be a particularly useful measure in experiments designed to test for differential cardiovascular responses.

Finger Pulse Volume

The finger pulse volume response to slide 1 was significantly different from the finger pulse volume response to slides 2–6. This was somewhat unexpected since prior research had shown that finger pulse volume decreases in response to both threatening and nonthreatening stimuli (see the review by TURPIN 1986). However, BLOOM/HOUSTIN/BURISH (1976) and BLOOM/TRAUTT (1977) had suggested that finger pulse volume is a measure more sensitive to threat than heart rate. The possibility that finger pulse volume is, indeed, a more sensitive measure of threat than heart rate seems indicated by the relative lack of variability of finger pulse volume response as compared to heart rate. Contrasts run to test for variability within the control slides produced no results approaching significance for the finger pulse volume measure. Perhaps, in contrast to the assumption drawn concerning the lack of control slide neutrality in the discussion of heart rate results, it is measure sensitivity that is producing variability. Seeing the eye spot pattern projected on a screen can pose no real threat to a subject. Consequently, if the eye spots are, indeed, "read" as

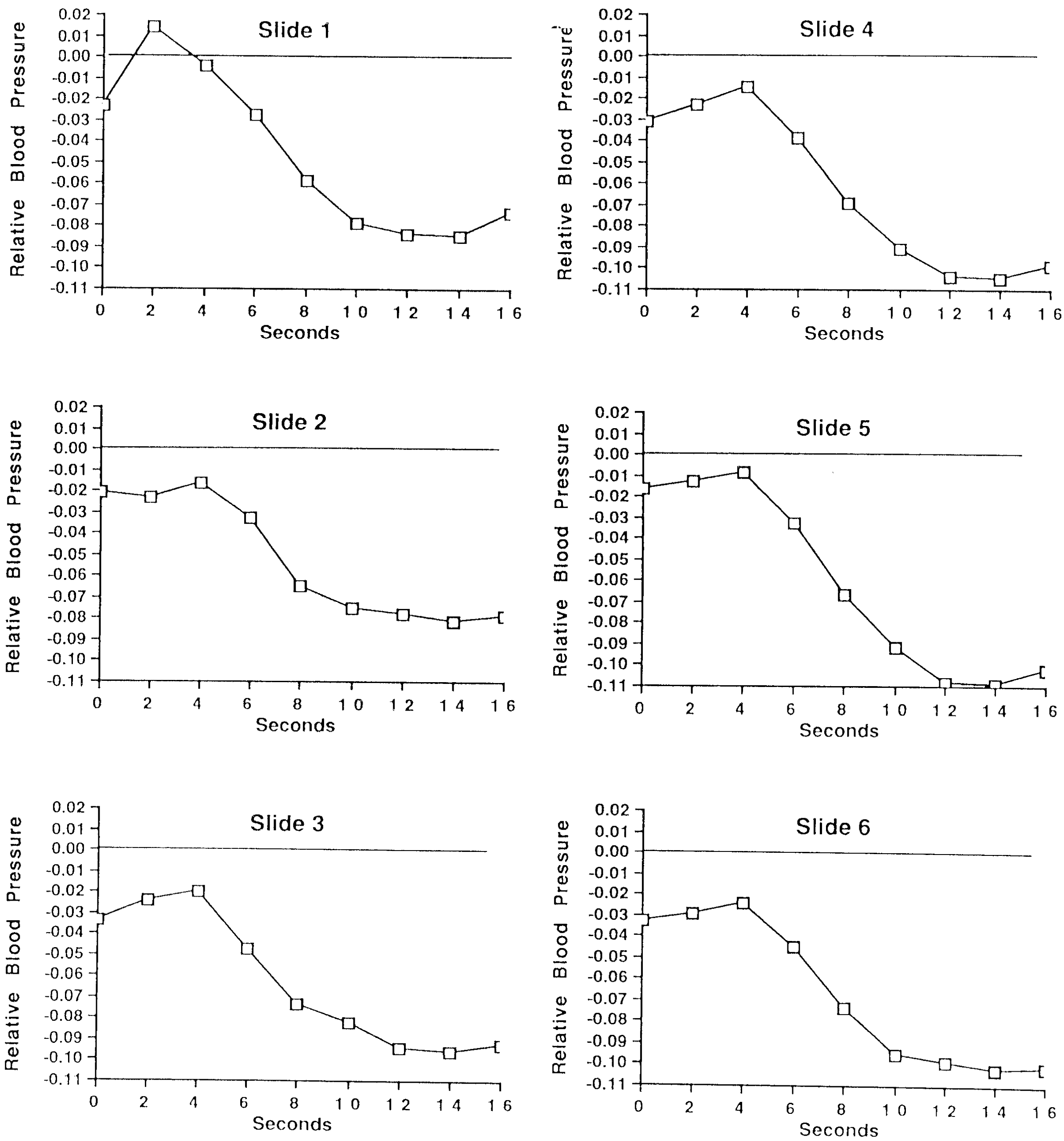

Figure 5: Relative blood pressure responses to slides 1 through 6.

threat by human beings, they can only stimulate a very slight response under this experimental setting. Note that the subjects had been shown all of the slides before testing began in order to counteract possible effects of startle or novelty. Therefore, a measure which has been regarded as possibly more sensitive to threat than heart rate would be expected to provide stronger results to a weak stimulus than would heart rate.

Thus, the cardiovascular responses to the eye spot pattern in this study were substantially different from the responses to the control slides. The responses seen in this study are phasic and complex making it difficult to draw simple conclusions regarding the nature of the responses. Comparing the patterns of response for all three measures to slide 1 does show that while blood pressure and finger pulse volume immediately increase at stimulus onset, heart rate does not respond for 2 seconds and then *decreases*. Then both blood pressure and finger pulse volume show substantial decreases while heart rate increases and then, decreases again. By the 14 second

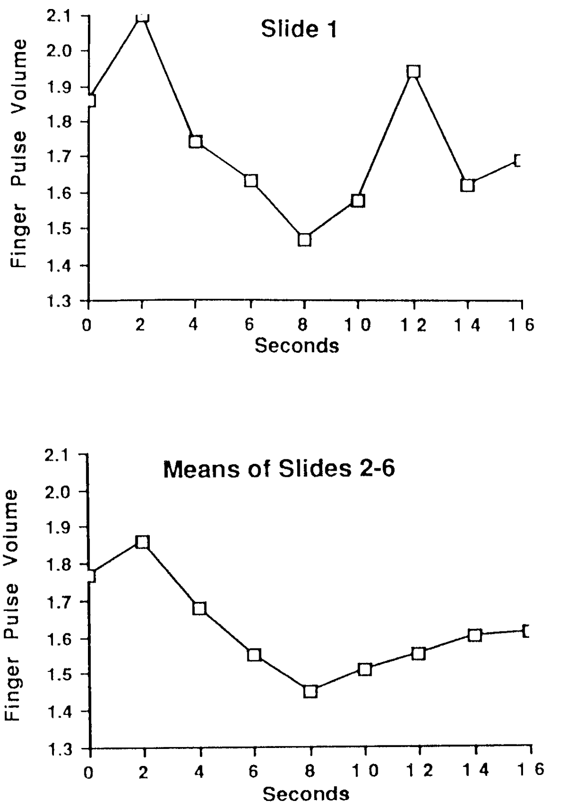

Figure 6: Means for finger pulse volume response to slide 1 and the composite of slides 2–6 across time intervals.

mark all measures are increasing. Since predictions could not be made regarding the nature of these responses because no one besides COSS (1965), who used pupil dilation as a measure, has studied human response to these simple abstract stimuli, it seems imperative that future research attempt to replicate the results from this study to see if these are, indeed, stable patterns of response. In addition, given the somewhat variable nature of the results, it would be advisable to use several different kinds of measures (e.g., evoked brain potential and pupil dilation) in tests of this kind rather than to depend on the results of just one measure.

Between Subject Factors

If, indeed, the differences found in this study between cardiovascular response to eye spots and control patterns indicate specific unconditioned responses do occur to threat stimuli, then these responses should be reasonably consistent throughout the species. One would expect differences to be minimal among cultures, between sexes, and among individuals. Thus, the finding that the 50 subjects responded as one group regardless of culture, sex, or response-type substantiates the notion that the response observed is unconditioned.

Considering the rather large amount of research indicating response-type differences in cardiovascular response, e.g., BLOCK 1957, (differences based on personality type); HARE 1973 and KLORMAN, et al. 1977 (differences based on phobias); and ZUCKERMAN 1985 (differences based on threshold of response), the results of this study are somewhat surprising. The fact that response-type differences were not found here may be due to two factors: (1) the protocol used to control the stimulus situation which may have resulted in a response unconfounded by extraneous environmental and motivational variables, and (2) the relatively large group of subjects which gave adequate statistical power to the data analysis. Adequate control of the stimulus situation and adequate power may have reduced variation due to extraneous variables enough to discover that, indeed, there may be no basic difference in response to this threat stimulus.

Conclusion

Eye spots are acknowledged threat stimuli for several animal species. This study used three cardiovascular measures, heart rate, relative blood pressure, and finger pulse volume, to measure human response to eye spots as compared to other circular patterns. A significant difference was found in the response between the eye spot pattern and the control patterns. On the other hand, the factors of culture, sex, and response-type had no effects. Thus, it can be concluded that human beings respond differentially to the eye spot pattern as do other animal species. Further research is needed to establish the consistency of the responses observed here to eye spots and whether other threat stimuli induce similar responses. Moreover, other components of the defense response should be used as measures testing response to eye spots and other suspected threat stimuli.

This study has implications in various areas of concern. The rather surprising result that all subjects responded similarly and did not fall into response-type groups raises questions regarding the response-type literature. Perhaps control of the stimulus situation and the testing of a relatively large number of subjects did remove variation that had been observed in other studies. Adequate control of the stimulus situation, i.e., removing extraneous stimuli, having a properly motivated subject, presenting the stimulus in random order, etc. is necessary to elicit a reliable response to an uncondi-

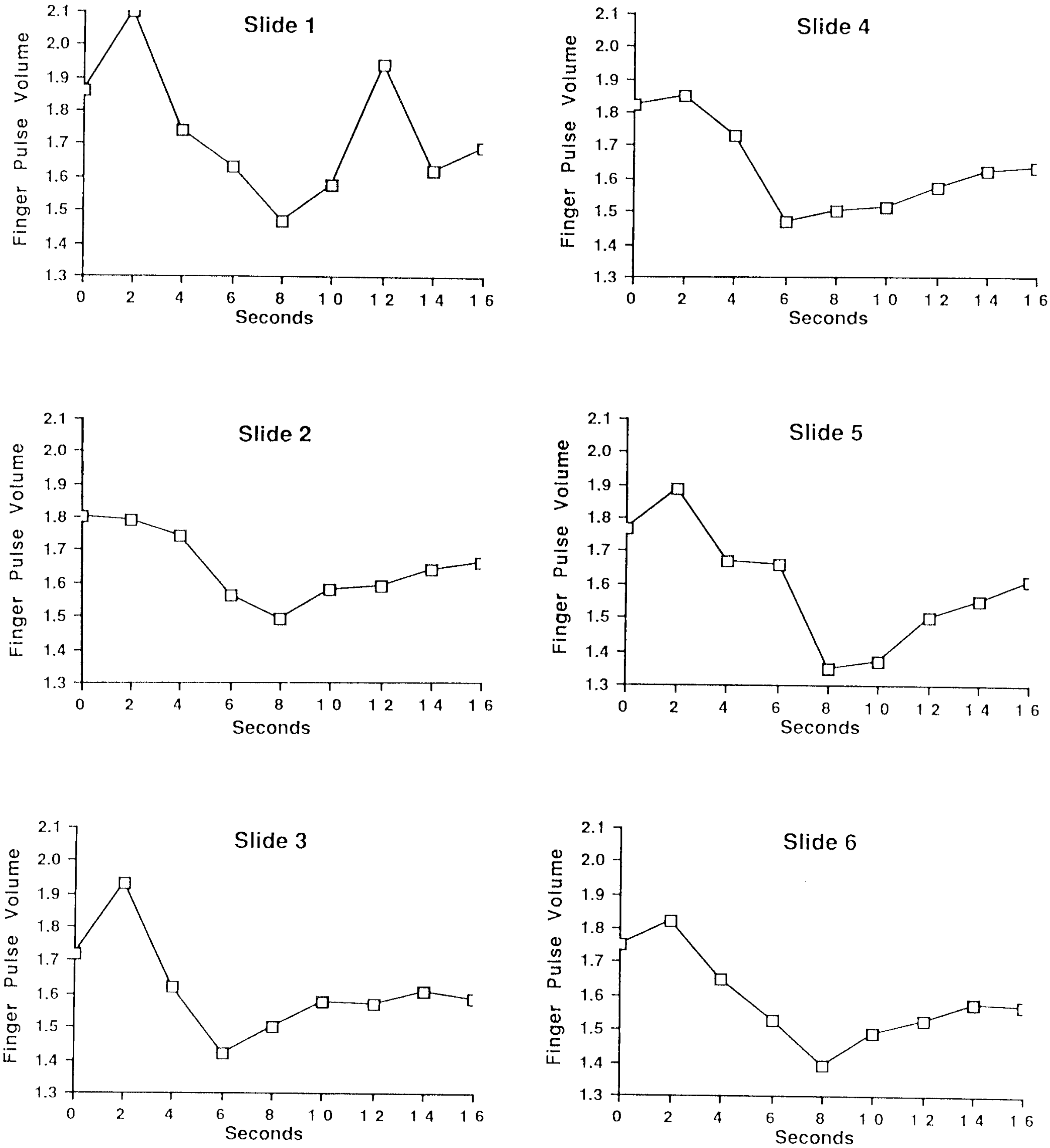

Figure 7: Finger pulse volume responses to slides 1 through 6.

tioned stimulus. (See TINBERGEN 1948 for a complete set of precautions to take in controlling the stimulus situation.) In order to ascertain what are reliable cardiovascular responses to visual threat, more studies are needed in which the stimulus situation is adequately controlled.

If, indeed, as is indicated by this study, human beings respond differentially to the eye spot threat stimulus with an unconditioned reflexive response to a biologically relevant stimulus, notions of salient stimuli and "template formation" in theories of cognitive processing might be considered in this light. This study suggests the possibility that human cognition and behavior might include reflexive responses of the type which heretofore have not been considered. That is, response to this threat stimulus suggests that human beings may respond differentially to

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other biologically relevant stimuli and that these responses may provide a basis for decision making and cognition in general. Evolution, then, has provided a reflexive basis for human cognition and this base includes adaptive responses to biologically relevant stimuli (stimuli which mean danger, food, procreation, etc).

Finally, this study provides support for a thesis discussed elsewhere (COSS 1968, AIKEN 1992 and AIKEN 1998) which suggests that human response to biologically relevant stimuli is a basis for the emotional impact of art. Stimuli, such as eye spots as utilized in portraits and other depictions of the face, are unconditioned stimuli which evoke changes in heart rate and finger pulse volume which can be experienced as emotional response. This emotional response often accounts for at least part of our response to art. I propose that response to such stimuli as eye spots is reliable and universal to the species. This study supports this notion. Other research also supports this theory because it traces the neural mechanism which makes possible this reliable, universal reaction to such stimuli. Joseph LEDOUX and colleagues (1992, 1994) have discovered that when our eyes see eye spots or another such stimuli the information rushes to the thalamus which sends the message to the amygdala. The amygdala processes the information and activates the defense center in the midbrain which speeds up heart rate, etc. LEDOUX (1992) hypothesizes that the thalamus may contain neurons capable of processing stimuli such as eye spots which are primitive cues for biologically adaptive responses such as running away from predators. Assuming LEDOUX is correct, the thalamus would contain neurons which fire when the cue is perceived. The cue need be only two circles placed horizontally side by side for eye spots. This fragment of information is enough to excite the thalamic neurons and cause them to send the message to prepare for danger. LEDOUX (1992) suggests that the sensory information that reaches the thalamus is crude; it consists only of features and fragments. Thus two circles can stand for eyes. Since reaction time in the face of danger can mean life or death, a "quick and dirty" path which allows one to react as quickly as possible makes evolutionary sense. LEDOUX thinks that the processing capacity of thalamic neurons projecting to the amygdala are adequate for this task.

A "slow but precise" neural pathway from the thalamus to sensory areas in cortex and then to the amygdala sends a clear picture of the stimulus which either confirms or denies the danger (LEDOUX 1992,1994). Therefore, a viewer of a work of art such as Picasso's *Les Demoselles d'Avignon* is excited by the eye spots and other exciting configurations used by the artist but realizes there is no danger because it is only a painting.

Emotional excitement is evoked without real danger by art.

The viewer of art, however, does not think this through consciously. The fast and dirty processing precedes conscious emotional experience and is, therefore, by definition, unconscious (LEDOUX 1992, 1994). Thus, we respond emotionally to the work of art but since the processing is precortical we are not conscious of the processing. We do not realize the eye spots have caused our arousal or attracted our attention which is, finally, brought to consciousness by the slow but precise pathway via the cortex. Then, we are apt to say that we like the work of art because it stirs our emotions. Thus, aesthetic response may have a biological explanation.

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Notes

1 Neutrality of the control patterns of circles relied on their meaninglessness as patterns. However, pattern 5, three circles in a vertical row, has meaning as a traffic light. This was not noticed until after the experiment had begun.

2 Although the seemingly lengthy response time could allow contextual contamination via thoughts, distractions, etc., earlier studies (see EVES/GRUZELIER 1984) indicate that without the long response period the nature of the response could not be evaluated, e.g., evidence indicates that the "defense response" is not observed in the first second or two for cardiovascular measures. A short response time may be appropriate for other components of the defense response. Additionally, using shorter scoring intervals (one second instead of two) would add more detail to the response data but would not change the basic quality of the response.

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Theresa S. S. Schilhab

Why Did Subjective Experiences Develop?

Abstract

Theories based on the DARWINIAN idea of "selection" as an evolutionary driving force may help to understand the workings and functions of human consciousness. The philosopher Daniel C. DENNETT has argued that consciousness was developed as a means to increase the rate of survival. However, it is one of the central features of consciousness that it "feels like something" to exist. Thus there seems to be a subjective quality of conscious experience. In philosophy of mind, this has traditionally been termed "qualia", and the term refers to for instance the sensation of red as opposed to the sensation of blue, or the complex feelings of pain or love. Any theory of consciousness must provide a satisfactory explanation of this phenomenon.

DENNETT claims that from a scientific perspective there is no problem of qualia. In our ancestors, qualia developed as a discriminative ability in order to structure the outside world, and did not entail any subjective qualities.

In humans, however, the subjective qualities came along with linguistic abilities, because these provide man with the possibility to relate to himself as an agent, i.e. regard himself from the outside.
Eventhough the discussion of qualia on this account can be dissolved, the question remains, whether DENNETT has succeeded in explaining why there is a subjective quality of conscious experience, i.e. why it "feels" like something to be conscious.

Key words

Consciousness, Daniel DENNETT, evolution, first order intentionality as opposed to second order intentionality, qualia, selective advantage, subjective qualities of conscious experience.

Introduction

It is beyond any doubt that theories of consciousness must be in accordance with scientific facts and therefore understandable in the light of the evolutionary theory as well. It is likewise true that any theory concerned with explanations of consciousness must deal with the problems of explaining why human consciousness implies "subjective experiences", such as for instance the sensation of red as opposed to the sensation of blue, or the complex feelings of pain or love. This means that the theory has to deal with consciousness taken in the sense: "a state it feels like something to be in", which was coined most comprehensively by the american philosopher Thomas NAGEL in his famous article "What's it like to be a bat?" (NAGEL 1974).

Why is it of importance that theories of consciousness also address the problem of the subjective qualities? The reason seems to be that subjectivity in particular is the central feature in need of explanation. A lot of philosophers and scientists working in cognitive sciences have been puzzled by this problem. There seems to be a major difficulty in explaining how these subjective phenomena relate to the scientifically describable neurons (NAGEL 1986; FLANAGAN 1992; AKINS 1993; CRICK 1993; GREENFIELD 1995; CHALMERS 1996).

One of the most consistent contributions regarding the origin of mental capacities comes from the american philosopher Daniel C. DENNETT, who argues for the development of consciousness as a means of increasing the rate of survival. This view was discussed partly in his books "Consciousness Explained", "DARWIN's Dangerous Idea" and elaborated in his latest book "Kinds of Minds" (DENNETT 1991; DENNETT 1995; DENNETT 1996).

DENNETT's aim is to discuss the evolution of consciousness in its broadest sense. Therefore he also investigates the subjective qualities of consciousness by focusing on the concept of "sentience" as opposed to "sensitivity" (DENNETT 1996). To DENNETT the distinction between sensitivity and sentience can be fruitfully coined by considering on the one hand the mechanical body-maintenance, which can be fully explained by sensitivity, and on the other hand the accompanying experiences of these mechanical properties, which require the additional feature of sentience. Thus, sentience is equal to sensitivity plus an unknown feature. *"Although activity in these ancient hormonal systems may be accompanied by powerful instances of what we presume to be sentience (such as waves of nausea, or dizzy feelings, or chills or pangs of lust), these systems operate independently of those sentient accompaniments, for instance in sleeping or comatose animals. […] Sentience is gone, but sensitivity of many sorts persists, maintaining various bodily balances."* (DENNETT 1996, p67).

In the philosophy of mind, what DENNETT here names sentience (in other words the subjective quality of consciousness), seem to me in one sense to be the phenomena that are traditionally known as qualia. Qualia refer to diverse phenomena described by names such as: "raw feels", "sensa", "phenomenal qualities, "intrinsic properties of conscious experiences", "a state it feels like something to be in" and "the qualitative content of mental states" (DENNETT 1991; BRADDON-MITCHELL/JACKSON 1996; CHALMERS 1996). DENNETT himself clarifies what is meant by the term in this way: *"Don't our internal discriminative states also have some special "intrinsic" properties, the subjective, private, ineffable, properties that constitute the way things look to us (sound to us, smell to us etc.)? Those additional properties would be qualia."*(DENNETT 1991, p372).

However, DENNETT also claims that qualia are nothing but mere illusions. He puts it this way:*"[…] I seemed to be denying, that there are any such properties, and for once what seems so is so. I am denying, that there are any such properties. But (here comes that theme again) I agree wholeheartedly that there seem to be qualia"* (DENNETT 1991, p372).

He is not the only proponent of this view normally referred to as "eliminative materialism" (CHURCHLAND 1989; SEARLE 1992; HARDCASTLE 1997). But the interesting feature in DENNETT's theory is that he provides an explanation for the phenomena named qualia, which in his theory become "the illusion of qualia" (my phrase), since as stated above he denies that there are any such qualities (RORTY 1993).

Since sentience is defined as the experience accompanying the mechanical properties it seems equal to qualia in the sense of being the subjective experience of consciousness. However, as is obvious from these quotations, DENNETT does not deny that the illusion of qualia, i.e. sentience, accompanies sensitivity, at least at the human level. There might not be qualia in the ontological sense, but it does not rule out that subjective experiences in the sense of sentience exist. But why then did sentience come about? According to DENNETT sentience came about in humans as a result of increased mental powers, especially the linguistic ability and as such because of its adaptive powers.

The radical view that human consciousness more or less consists of our linguistic capabilities leads to some fascinating consequences. This is however far beyond the scope of this paper. In what follows I will try to outline the crucial aspects of DENNETT's theory as presented in "DARWIN'S Dangerous Idea" (1995) and "Kinds of Minds" (1996), since it seems to me to offer a bold and constructive explanation of the development of mind within a scientific and more specifically a phylogenetic framework. In these books DENNETT does not directly address the problem of subjective experiences in the sense of qualia. This he already did in "Consciousness Explained" from 1991, where he argued, that we should not accept uncritically what manifests itself introspectively (DENNETT 1991; RORTY 1993; AKINS/WINGER 1996). Even though DENNETT might successfully have solved the problem of qualia, we are still left with the problem of sentience (DENNETT 1997). Therefore it seems fruitful to investigate whether his elaborated evolutionary theory of consciousness can also account for the development of sentience.

In what follows I will try to outline his theory as faithfully as possible and investigate the explanation with regard to this point and try to demonstrate that in spite of its plausibility with regard to the development of pure cognitive capacities (i.e. mental states lacking subjective feelings), the theory still seems to lack a satisfactory explanation of why sentience developed, and why these conscious states *feel like* anything at all. Since DENNETT puts emphasis on the distinction between sensitivity and sentience in order to explain the development of minds, I will present examples that seem to me to refer to either the first or the second concept, whenever possible.

The phylogenetic perspective on consciousness

DENNETT proposes that all organisms are subordinate to the basic principles of natural selection. What comes to be rational in this scenario is what increases the chances of survival. In other words, whenever there is self-replication, those organisms that are most likely to respond adequately to the conditions of the environment will be favored (DENNETT 1996 p32). This general principle applies to the development of the mind as well. Therefore, DENNETT claims that the rationale for the development of all cognitive systems consists of the ability to anticipate the future, and especially which actions would be preferable to the organism. Furthermore, in order to be able to anticipate, there is a need of representing the crucial features of the environment. Therefore the evolution of cognitive systems is nothing but the evolution of more and more refined ways of representing the environment. The term representation does not imply that there is a one-to-one projection of the world unto the cognitive system, but only a symbolic "picture". As DENNETT himself puts it: *"We must be very careful not to think of the inner environment […] as simply as a replica of the outer world, with all the physical contingencies of that world reproduced."* (DENNETT 1996, p89).

These basic principles of mind apply to all cognitive systems. Thus if we are to understand the human mind, we must attend to theories of how it developed. DENNETT proposes a tentative division of designs of minds into four categories, which are only meant as a system of classification (DENNETT 1995, p373). He emphasizes that the categorization is to be taken in the sense that it captures the qualitative differences between kinds of minds and not that of a complete categorization. Therefore, in real life all sorts of intermediate stages exist, but the aforementioned four categories classify the important qualitative differences between these systems.

First level: The Darwinians

The first category assigned a kind of mind is the category of *DARWINIAN creatures*. These are born with phenotypic traits, entirely determined by their genetic make-up. This means that during the lifetime of the organism, the interactions with the environment are exclusively determined by the genetic equipment, since the phenotypic traits are not susceptible to environmental influences. The mind at this level is a system which primitively represents the environment by way of sensitivity to certain environmental stimuli. Those features of the environment that are of interest to the organism are thus "represented" by the elicitation of the response. Its function is to monitor and subsequently adjust the local interactions in order to protect the organism, and therefore DENNETT names it "The Body Maintenance System". DENNETT claims: *"Animals have had slow systems of body-maintenance for as long as there have been animals. Some of the molecules floating along in such a media as the bloodstream are themselves operatives that directly "do things" for the body (for instance, some of them destroy toxic invaders in one-on-one combat), and some are more like messengers, whose arrival at and "recognition" by some larger agent tells the larger agent to "do things" (for instance, to speed up the heart rate or initiate vomiting). Sometimes the larger agent is the entire body."* (DENNETT 1996, p.66).

In order to understand that this capability does not require any kind of consciousness, but somehow does refer to a rudimentary sort of representational system, it is helpful to think of the primitive organism *Paramecium*. The fact that this organism has no nervous system is without significance to the question of sensitivity versus sentience. This organism swims about in a manner entirely determined by the automatic responses of Ca^{2+} intake and release. Even though the behavior seems purposeful and rational, one would not feel inclined to attribute any sort of conscious reasoning to this organism.

Second level: The Skinnerians

At the DARWINIAN level, the behavioral repertoire is limited. Hence it is strategic to possess the ability to discriminate and to consolidate the experiences of encounters with the environment in memories. This leads to the second level of kinds of minds, and the organisms capable of that task are called *SKINNERIAN creatures*, because they are capable of the sort of learning that SKINNER named "conditioning". These organisms have the ability to weight/judge the encounters—in those that are preferable—and those that are better to avoid, and then consolidate this information in their behavioral repertoire. This mechanism amounts to an association of the incidence of experience with an appropriate response, that is either reinforced or extinguished (at the neuronal level the response becomes either facilitated or depressed). Again, the ability to associate something preferable or repugnant with a certain encounter is not dependent on whether the organism is conscious of this judgment. This is strongly supported by ethological experiments done on invertebrates—the snail *Helix pomatia*, for instance (NIELSEN et.al. 1993; SCHILHAB/CHRISTOFFERSEN 1995).

In these experiments *Helix pomatia* (in the learned condition) gets a "negative" signal, since it seems "painful" to the slug, from the environment.

So, initially, we have in the naive condition:

1. The slug meets a stimulus (food item)
2. It eats continuously.

Now we test the slug (which has been deprived from food for a while) in a trial (to see the consequences of a presumed "negative" encounter with the environment, which we are controlling by applying a noxious stimulus to its tail):

1. The slug meets the stimulus (food item).
2. The slug eats, and this is followed by a second stimulus—the electrical stimulus at its tail.
3. It stops eating.

Next trial we see the consequences—has it been consolidated in a memory—does it learn?

1. The slug meets the stimulus (food item).
2. The slug doesn't eat or just eats very slowly (diminished response).

(It has learned the association between that certain food item and the electrical stimulus applied to its tail).

Now, what does this show? Intuitively we call the unconditioned response (here the noxious stimulus) "pain". But why is that? Simply because it makes the slug avoid the signal. And why do we call it a negative signal? Just because it will most likely avoid such encounters later on (showing that the situation has been consolidated in a memory). To summarize, only because the slug subsequently avoids the food item, do we acknowledge that the electrical stimulus is recognized as a "negative signal from the environment" by the slug. This lead us to the question of how does the snail feel, how does it "recognize" that the electrical stimulus should be avoided in the situation, where it associates the food stimulus with the electrical stimulus for the first time?

It is most probable that the slug doesn't "know" that the stimulus is a "negative" signal, since it is just wired in a way which makes its response diminish. And the only reliable explanation of this wiring is that it has been favored by selection.

So it is not possible for the organism to "know" in advance, whether the signal is good or bad in the long run. And we are inclined to deduce that since the response diminishes, it must be recognized as a "negative" signal.

Third level: The Popperians

The SKINNERIAN system, however, is based on training, which can only be obtained through actual encounters with the environment, and these creatures are therefore not equipped to cope with devastating one-trial encounters. From this follows that it is highly preferable to possess the ability to select among a number of alternative actions *before* the actual encounter takes place. This is realized at the third level of kinds of minds, and DENNETT calls creatures possessing this ability the *POPPERIAN creatures,* because, as POPPER once famously said this design enhancement: "permits our hypotheses to die in our stead". (DENNETT 1996, p88)

The preselection is obtained exclusively in "thought", in the sense of unspecified mental activity. This means that it does not rely on actual encounters. Therefore in order to make this anticipation system work, it seems to require a connection between some sort of "cognitive map" (some internal representation), and another mental feature playing the "judgmental" part. More specifically, the internal representation of the external world must be provided in such a form that the organism will be able to judge whether any contemplated action is preferable or not. Even though this strategy seems to be entirely different from its predecessors, at the level of physiological processes this is not the case. The strategy can be fully explained by an increase in the complexity of neural connections. In DENNETT's own words: *"But how is this preselection in POPPERIAN agents to be done? Where is the feedback to come from? It must come from some sort of inner environment—an inner something-or-other that is structured in such a way that the surrogate actions it favors are more often than not the very actions the real world would also bless, if they were actually performed. In short, the inner environment, whatever it is, must contain lots of information about the outer environment and its regularities"* (DENNETT 1995, p375).

Again, this mental act does not involve any subjective experiences, since the internal representation is nothing but a highly advanced perceptive capability neurally connected to the mechanism of sensitivity, which was already introduced at the level of DARWINIANS.

Preselection of the action comes about because of the wiring of an internal representation to a certain bodily response, for instance the neural network responsible for nausea (without the company of subjective experience). This wiring is caused by evolution and determines whether the anticipated action will be performed, and therefore it becomes clear, that here it plays the part of "judgment" as seen from this quote: *"One of the ways POPPERIAN Creatures achieve useful filtering is by putting candidate behavioral options before the bodily tribunal and exploiting the wisdom, however out-of-date or shortsighted, accumulated in those tissues."* (DENNETT 1996, p90).

Hence, when the POPPERIAN organism is normally situated it perceives an enormous amount of information. This activates a huge amount of receptors connected downstream to many different networks responsible for the behavioral output. Being confronted with for instance the sight of fire activates specific receptors, which are connected to the neuronal subsystem that subsequently leads to the inhibition of walking in the direction of the fire. There is no need to attribute any subjective feeling of fear, since it plays no part in the escape. Even though the organism has never been acquainted with the damaging effects of fire, the inhibition provoked by activity of certain receptors interferes with the subsequent behavior. This bunch of behavioral responses with the general structure: if stimulus X, then response Y is roughly, what to DENNETT amounts to the improved system of anticipation.

Fourth level: The Gregorians

With the human cognitive system (the GREGORIAN: named after the British psychologist James GREGOR, because of his emphasis on the role of information) the type of mind is created which is sentient beyond doubt. This is crudely put, caused by the fact that the human cognitive system has, in addition to representing the environment, the ability to represent itself in relation to the environment. Since the above mentioned cognitive systems can be described as basically identical in structure, but different from each other by an increase in the complexity of neural connections, the crucial point is how this new invention—sentience—comes about? Does it rest on a qualitatively different way of structuring neurons or does it come about as the result of increased complexity?

DENNETT proposes a feature which seems important to the phylogenetic qualitative leap from nonconscious cognitive systems to human cognitive systems, that is, if any are conscious. What seems crucial is that the improvement in representing the environment opens up a completely new way of organizing information. If one cognitive system can compress more and more information and still obtain a selective advantage, this system will flourish. This ability is analogous to labeling and is met most satisfactorily in humans by the invention of the linguistic capabilities. DENNETT claims: *"There is no step more uplifting, more explosive, more momentous in the history of mind design than the invention of language. When Homo sapiens became the beneficiary of this invention, the species stepped into the slingshot that has launched far beyond all other earthly species in the power to look ahead and reflect."*(DENNETT 1996, p147). Language is a favorable form of representing the environment, since it organizes more information with less cognitive load. According to DENNETT: *"Putting deliberate marks on the environment to use in distinguishing what are for you its most important features is an excellent way of reducing the cognitive load on your perception and memory"* (DENNETT 1996, p135). The use of concepts leads naturally to a system, where the marks themselves (words or concepts) become the objects of mental manipulation. DENNETT emphasizes this by: *"In GREGORIAN creatures such as us, the representations of features and things in the (external or internal) world become objects in their own right—things to be manipulated, tracked, moved […] and exploited. […] Words make us more intelligent by making recognition easier, in the same way that beacons and landmarks make navigation in the world easier for the simple creatures."* (DENNETT 1996, p143).

The linguistic feature makes organization of information easier by means of conceptualizing it. Thereby information can be applicable to a rule. DENNETT claims that to social animals like ourselves there is a selective advantage in being able to predict the future actions of fellow actors, which is equal to being able to predict their intention. By it does not follow, as mentioned above, that our fellow companions *are* intentional (i.e. that they are holding beliefs and desires in the sense that we humans do). But if one is able to interpret intentions of other animals, fellows or enemies alike, even though they are not really intentional, it seems plausible that the same method applies to one self. Therefore the linguistic capability seems to entail that we can become able to reflect upon ourselves in relation to the world.

From this seems to follow that the difference between the other cognitive systems and the human is that the former are first order intentional systems and the latter is a second order intentional system. This implies that while representations in the former systems are simply "desires", "wishes" and "beliefs" (lacking any subjective experience), the human system, besides the desires, wishes and beliefs, is capable of representations of desires, wishes and beliefs. In other words, while the chicken watches the falcon, the neural network responsible for flight is activated. And this neural activity leading to the flight behavior is exactly what is meant by the "desire to escape". The mechanism is no different from what happened in the case of *Helix*, except for the complexity of the involved neural network.

In humans faced with danger there will likewise be an activation of the relevant network responsible for the flight behavior. Here again the relevant stimuli are the sight of the danger. However, the activation of this first order representation along with the second order representation is somehow simultaneously responsible for the accompanying subjective experience, that is, to consciousness.

Consequences and implications of the theory

According to the evolutionary theory of minds offered by DENNETT, the human cognitive system developed as a consequence of its adaptive functions. Since at the human level sentience is beyond doubt introduced, the crucial point is on what basis does DENNETT claim that the ability to represent oneself in relation to the environment (manifested by our linguistic ability) gives rise to sentience?

The reasons given seem primarily to involve the rationale of "Mother Nature", which is the metaphorical name for selective advantages. Because of the selective advantage in using linguistic representations to anticipate the future, second-order-intentionality was realized. Now, if understood correctly, it seems to me, that in order to incorporate an explanation of this feature, only two propositions are available. Either sentience developed as a by-product, having no function in the overall strategy whatsoever, and as such is nothing but an epiphenomenon. Or sentience was somehow selected for, since it increased the rate of survival. If sentience is just the result of the advanced representational ability seen in the human cognitive system, there is still the residual problem of explaining why the human neural organization gives rise to subjective experiences. Just stating that sentience is a by-product of the improved anticipatory system does not explain how sentience relates to the mechanical features of the nervous system and why having sentience feels like anything. My objection is, why does it follow that second order beliefs part company with subjective experiences?

In some quotes, however, DENNETT seems to suggest that sentience increased the overall fitness of the GREGORIANS. This interpretation seems in accordance with a quotation regarding the feelings of pain: "*There can be no doubt, that having the alarm system of pain fibres and the associated tracts in the brain is an evolutionary boon, even if it means paying the price of having some alarm ring that we can't do anything about. But why do pains have to hurt so much? Why couldn't it just be a loud bell in the mind's ear for instance?*" (DENNETT 1991, p61).

If sentience itself was selected for, it is still necessary to explain why the feeling has a selective advantage.

The crucial point is that, on the basis of the evolutionary explanation, neither of these interpretations seem to give an adequate account of why sentience arose at the human level.

Concluding remarks

No doubt the postulate that the development of linguistic abilities is largely responsible for the superiority of the human mental capacities is supported by scientists from a large number of disciplines (ENGELSTED 1984; ULBÆK 1984; GIBSON/INGOLD 1993; PINKER 1994; NOBLE/DAVIDSON 1996). The question is here whether it can also account for the subjective feelings accompanying some of our mental states? I have tried to investigate whether the explanation offered by DENNETT does provide a satisfying account of the relation between this feature and sentience.

To summarize: the explanation that DENNETT is offering as to how and why sentience came about seems to be connected to adaptive function of the human cognitive system. In the anticipatory organisms at an advanced level such as the human, the exploitation of the functioning of the body-maintenance system, combined with the ability to represent the inner and outer environment, resulted in organisms that were sentient.

If this account captures the essential features of evolutionary processes leading to the development of sentience in broad lines, then it seems to me that DENNETT's explanation still leaves out the truly mysterious part concerning subjective feelings, since this explanation in no way gives a credible account of why and how sentience *has to feel like anything* at all. It seems to me that no part of the theory explains why sentience came about, since the body-maintenance system (as explained by DENNETT) could easily provide the inheritor with the functioning of maintenance of the body, without the accompaniment of conscious experiences. A probable objection to this would be to postulate that the body-maintenance system connected neurally to an anticipatory ability *accompanied by* subjective feelings somehow increased the flexibility, and therefore the fitness of the organisms (FLANAGAN 1992). With regard to the subjective experiences of for instance pain the argumentation seems to be that it is beneficiary to the organism to sense pain, since it makes the organism withdraw from the painful stimuli (DENNETT

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1991; HARDCASTLE 1997). This is further illustrated by the fact that people lacking the ability to sense pain are in constant danger of hurtful interactions with the environment (HARDCASTLE 1997). This is of course true, but does it allow one to infer that subjective experiences of pain developed as a means to "warn" the organism of danger? Does it rule out that this "warning" could be obtained by pure neural activity lacking sentience, as seen in *Helix*?

To me, however, this seems more like a reconstruction, or a description of the actual state of things than an explanation. It does not provide any reasons for why and how a combination of the ability to discriminate the environment and the ability to represent the environment results in "states it feels like something to be in". *"But why do pains have to hurt so much? Why couldn't it just be a loud bell in the mind's ear for instance?"* DENNETT asks himself. Why does pain have to hurt? In sentient beings like humans, could not pain just be registered in the same way as in purely sensitive systems, i.e. without associated consciousness? This would by no means prevent the anticipatory beings from exploiting the wisdom of the body-maintenance system, since the resulting rational actions would still pertain. Therefore, even though DENNETT's theory of the evolution of minds within a naturalistic framework offers a promising step towards a more profound understanding of consciousness it still leaves the question of why subjective feelings feel the way they do unanswered.

This may be due to the fact, as pointed out by AKINS, that in the end the very question of why subjective feelings feel the way they do must change before it we can understand consciousness and its features by way of the scientific strategy (AKINS 1993).

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Johannes Gadner

Embodying Culture

On the Socio–Cultural Influences on the Development of Cognitive Structures. Anthropological Contributions to the Concept of Embodiment

Abstract

This article attampts to establish a theoretical framework for a comprehensive theory of ontogenetice development of human cognition that takes into account the socio–cultural nature of man. Cognitive anthropological evidence suggests that the formation of cognitive structures cannot be exempted from the interaction of man's biological makeup and its specific developmental contexts. The concept of enculturation maintains that phylogenetic principles are a flexible framework within which a socio–culturally structured ontogeny occurs. Enculturation is defined here as the embodiment of culture, which dismantels the traditionally held dichotomy between biology and culture. The role of anthropology within the field of cognitve science is discussed.

Key words

Cognition, interaction, ontogeny, embodiment, enculturation.

Introduction

With the recent acclamation of the 'Decade of the Brain' the process of perception and cognition and its result—the *image* we create of reality—has become a heavily discussed field of interest within different scientific disciplines. As will be seen, this process is highly constructive and depends on various factors. For PIAGET cognition is based upon self-regulated internal constructions (PIAGET 1974, p323). But the sole attention to the biological and evolutionary basis of cognition cannot sufficiently explain its structures, organisation and function. Genetic epistemology and later cognitive–scientific presumptions have neglected the role of society and culture within this process. As in any scientific or explanatory approach the claim to understand complex processes through reductionistic models is certainly overdrawn. A phenomenon like our image of reality seems to be far too complex to be explained by one single factor. A comprehensive theory of cognition has to take into account that every single factor in an interdependent self-organizing system contributes significantly to the final structure of the whole complex.

From an anthropological[1] point of view we must face the fact that different cultures construct and perceive their specific reality with all correlating implications (BOURGUIGNON 1979, p230; GINGRICH 1993; WEISS 1987, p161f.). These lead us to assume that cognition is not merely the product of human phylogenetic evolution and genetic predispositions but to an equivalent degree the result of interaction between individual human beings and their natural and socio–cultural environment. The sources of cognition consist of the individual biological makeup as well as on various developmental contexts which BRONFENBRENNER (1979) subdivided into a) the immediate environment, b) the socio–economic and c) the cultural context.

The attempts to explain cognition from a reductionistic viewpoint have not been very successful. On the contrary—according to ARTIGIANI (1996, p2)—the paradigm of self-organizing systems exemplifies the limitations of this rather 'traditional' explanation. We implicitly notice here that a substantial discourse concerned with the phenomenon of cognition breaks through the boundaries of scientific disciplines. Yet, it has to be acknowledged that there exists no "royal road" to understand cognition that works on the basis of independent scientific methodologies or disciplines (Einzelwissenschaften). Cognitive science faces extensive progress through recent methodological developments in AI or neuroscience and consequently exerts extensive influence on anthropological theories and research work. By the same token, however, it has to be stressed that anthropological findings have always had and still have a major impact on cognitive scientific theories.[2] The attempt to esablish a biologistic–reductionistic oriented theory of cognition that is blind to consider socio–cultural differences and their influences on ontogenetic development as well as cognitive structures is certainly challenged by anthropological findings. Indeed, the task of anthropology within this discourse is to help dismantle the intellectual boundaries that currently seperate the humanities from natural sciences (INGOLD 1992, p693).

This essay will raise the question of which variables and to what extend might influence the ontogenetic development of the child and its cognitive structures. Obviously, the biological development takes place in a specific contextual framework—that has been referred to as the "motherhood constellation" by STERN (1995)—without which the human infant definitely cannot survive. This framework itself is embedded in a fundamental environmental whole referred to as culture. Thus, a major point of interest will be to investigate socio–cultural factors within the ontogenetic process. As we know from anthropological research this is a process that gradually transforms the human infant into a mature member of a society within a specific cultural tradition. In anthropology, this process is generally addressed with the term enculturation. The concept of enculturation implies not only the fact that a child has to adapt to the specific external reality into which it is born, but also that modes of development vary immensely regarding to the specific contexts within which they progress (VIVELO 1981, p168).

An explanatory approach to the phenomenon of human cognition should therefore take into account the relevance of environmental (external) influences on the process of the formation of mental (internal) structures. The first aim of this article is to provide an outline of a framework which seriously considers the different factors that influence ontogenetic development. Secondly, it is argued why for that concern especially the concept of embodiment as well as similar, related concepts are important for cognitive anthropology or any field of cognitive scientific research.

In order to find an adequate way of argumentation, several particular steps seem to be required: The first effort will be to discuss briefly various approaches to the process of perception and cognition. The intention of the discussion is to demonstrate the necessity of bringing different conceptions to a synthesis. The next step will be a summary of both the concept of embodiment as well as the processes which lead to embodied cognition. In addition to that we will debate—in a third step—the effect of socio–cultural factors such as abstract concepts as beliefs or *common sense*-representations on the cognitive structures, and thus the perception of reality. Finally, the question of what a cognitive model of culture has to be like and where culture is to be located is addressed.

Representation vs. enaction and the origin of mental reality

Different theories of cognition provide their own concepts of what cognition is and how it might function. Examining these concepts, we discover that their main assumption—that the world is *represented* (ROTH 1995, p28f, p232, p278ff) or *enacted* (VARELA 1991, p98ff; VARELA/THOMPSON/ROSCH 1992, p173) in the mental structures of the individual—just differs in the terminology. For example, VARELA and MATURANA criticize the theory of representation due to the notion and concept of representation. They claim that the concept is incapable of explaining how an external object can be mentally *re-presented* if it has not been present in the mind already (VARELA 1991, p98ff; MATURANA/VARELA 1987). This critique seems to caricature a kind of 'Abbildtheorie' which believes that the brain reflects the world as an objective duplicate. Actually, this rather naive idea with all its immanent consequences neither exists in philosophy nor neurobiology (OESER/SEITELBERGER 1995, p136) and hence demonstrates the redundancy of this critique. Subsequently, we will discover that both notions—representation and enaction—may be used equally to express the same neuronal processes and mental *re-actions*. The only problem evolving out of both concepts is that the specific neurological processes and correlates relating to them are generally unknown (ENGEL/KÖNIG/SINGER 1994): Neurological evidence of the theory of representation as well as of enaction is tenuous reflected by the uncertainty and perplexity of the scientists who are working on the solution of the riddles underlying these phenomena (ROTH 1995, p252ff; BIERI 1994, p173ff). Due to the complexity of mental activities one is tempted to predict that the question of which neuronal correlates represent perceived objects or circumstances will probably remain unanswered (ROTH 1995, p252ff; METZINGER 1996, p19f).

A closer examination of the definitions and conceptions shows that a constructivist approach using the concept of representation can almost be assessed as equivalent to one using the concept of enaction. As we proceed, these as yet somewhat unclear notions will become more transparent. First of all, we can assume that divisions within the cognitive sciences concerning that special point of interest are more or less arbitrary. The History of Science has shown that an interdisciplinary, dialectical approach makes much more sense than an obviously not scientifically motivated discourse about definitions (HABERMAS 1973/1985, p206; GRIPP 1984, p33; FEYERABEND 1986, p15, p21ff, p37, p301ff). In this article the attempt is made to combine distinct notions and concepts in order to show that the boundaries between them are mutually permeable and transcendent.

CIOMPI and WIMMER point out that a current trend in neurobiology tries to operate with rather broad definitions which may cover overlapping and even contradictory domains (CIOMPI/WIMMER 1996, p39f). This trend of argumentation has been generally accepted by proponents of different disciplines like philosophy or anthropology as well, although with slightly different connotations (METZINGER 1996, p18; CLIFFORD 1986). However, the lack of a strictly defined notion turns out to be an advantage in a domain of very subtle nuances which cognitive science definitely is (CIOMPI/WIMMER 1996, p39). To speak with Konrad LORENZ, the scientific definition of a notion can only be a fictitious solution to a problem (LORENZ 1973, p63ff). Moreover, LORENZ proposed the method of 'intuition' to gain knowledge about correlations between distinct entities or processes that seem to be disconnected in materialistic explanations (LORENZ 1992, p127; WUKETITS 1990, p52). Eventually, this cognitive scientific trend is summarized as a need for hermeneutic concepts that use metaphorical descriptions of neuronal functions (LINKE 1996, p26).

On the contrary, Patricia CHURCHLAND argues that categories like 'Gedächtnis' (memory), 'Aufmerksamkeit' (attention) or 'Wunsch' (wish) used by contemporary philosophers and psychologists to explain mental and cognitive phenomena will disappear very soon (CHURCHLAND 1996, p466f). This kind of revisionism is legitimate because we do not understand which mental and neuronal processes fundamentally engender these states of mind (CHURCHLAND 1996, p467). However, ROTH's objection to 'eliminative materialism' draws the attention to the difficulties of transferring the above categories and phenomena like consciousness or 'Geist' directly to specific states of mind and vice versa (ROTH 1995, p266ff). The present state of the art in the field of neurological research suggests that we have to accept that neurons themselves are not capable of an activity like 'thinking' or representing internal or external objects. The previously existing assumption that single neurons have the capacity to detect or perceive an object has been falsified. Moreover, it seems to be very difficult if not impossible to state neuronal correlations with cognitive processes at all (ROTH 1995, p268; METZINGER 1996, p21ff; CRICK/KOCH 1994; BIERI 1994). Thus, we are in need for a better explanation of cognition that takes into account that the individual brain is not the only source of mental processes and—since it evolves embedded in a system of interactions—cannot be understood as an isolated system.

Cognition as embodied action

The different constructivist approaches of ROTH (1995, p278ff) and VARELA (VARELA/THOMPSON/ROSCH 1992, p172f) as well as the neuroepistemological approach of OESER and SEITELBERGER (OESER/SEITELBERGER 1995, p146ff) suppose in very similar ways that a pregiven outer world and the specific reality in our brain differ in their fundamental essence on the one hand and build an interdependent connection on the other. To illustrate this delicate interrelation, VARELA poses a simple question: "Which came first, the world or the image?" (VARELA/THOMPSON/ROSCH 1992, p172). We should not hope to find a solution in either the chicken position (which sees the perceptive image of the world as a perfect duplicate) or the egg position (for which the cognitive system projects an arbitrary inner world) as both realists and idealists do, for both extremes cause and define each other in a specific way (VARELA 1991, p102).

The interdependent relationship between the outer world and the mentally constructed inner world has a fundamental meaning in the process of ontogenetic development (GLASERSFELD 1981, p32f). This interdependence is consistent with the theory of Jean PIAGET, who conceptualized the formation of cognition by assuming an interplay between adaptive internal processes and external, environmental flows. The infant's only capacity within this process is the activity of assimilating the outer world into its own cognitive structures or to accommodate these structures to the external world, if they begin to work insufficiently (PIAGET/INHELDER 1990, p11; PIAGET 1954).Consequently, the external reality consisting of manifold types of objects is to be considered as valid and known only in the same measure as it (or respectively the objects) has (have) become cognitively structured (PIAGET/Inhelder 1990, p19).

It is indeed very tempting to introduce a psychoanalytic oriented approach to conceptualize the process of coming–into–being of the mind and the formation of cognitive structures. According to this, metaphorically speaking, the objectively perceived object is constituted by a subjective object of the infant. This means that during the ontogenetic development the object is created by the infant and not just found through 'pure perception' (in a KANTIAN sense).[3] Thus, the construction of an external reality relies on internal representations. The paradox of this process—as WINNICOTT calls it—is that, nevertheless, the object has to be found in order to be created, which means that it already has to be there! But simultaneously the object does not exist for the infant if it has not been mentally created (WINNICOTT 1945; 1969). MURRAY (1989), in a comparison between evidence from research in developmental psychology and the described psychoanalytic concept, refers to the similarities and compatibilities of PIAGET's and WINNICOTT's theories.

The analysis of this complex process demonstrates how closely outer and inner world relate to each other, so we cannot speak of an outer world without taking the inner world into consideration and vice versa. Actually one might ask if, after all, it is legitimate even to think of a reality which exists outside this interdependent relationship. Indeed, this leads us to a rather philosophical question while we try to find a way to combine the chicken position with the egg position. For that we provide a definition of cognition as an active and constructive process (ROTH 1995, p28f) or—to speak with VARELA et.al.—as embodied action (VARELA/THOMPSON/ROSCH 1992, p172). The phrase embodied action may be explained more intelligible: "By using the term embodied we mean to highlight two points: first, that cognition depends upon the kinds of experience that come from having a body with various sensorimotor capacities, and second, that these individual sensorimotor capacities are themselves embedded in a more encompassing biological, psychological, and cultural context. By using the term action we mean to emphasize once again that sensory and motor processes, perception and action, are fundamentally inseparable in lived cognition. Indeed, the two are not merely contingently linked in individuals; they have also evolved together." (VARELA/THOMPSON/ROSCH 1992, p172f).

Proceeding from these assumptions, based on neurophysiological research findings as well as on cognitive psychology and anthropology, we discover a multiplex connection between biological predisposition and environmental interaction which both together structure the development of cognitive processes. This multiplex connection of external and internal factors can be seen as a fundamental concept for any constructivist theory of cognition and thus paradoxically defeats VARELA's and MATURANA's critique mentioned above.

Contexts of embodiment

The concept of cognition as embodied action gives the impression of a perfect combination of previous theories, although it does not explicitly refer to them. PIAGET has shown in detail that all kinds of cognitive structures seem to be generated through action (PIAGET 1977). According to CIOMPI's concept of 'Affect–Logic' these structures have to base on emotions because actions without affects do not exist (CIOMPI/WIMMER 1996, p41). VYGOTSKY agreed with PIAGET in one point when he stressed that the child's most important capacity is the active participation in shaping his or her cognitive development (VYGOTSKY 1964, p79; LEONTJEW/LURIA 1964, p3). But he challenged PIAGET's theory when he emphasized the importance of social interactions concerning the formation of cognitive structures. In other words, the process of cognition depends equally on psychobiological capacities of the human species and on various kinds of individual affects, action and experience (ROTH 1995, p29, p298ff; BOURGUIGNON 1979, p200; LEONTJEW/LURIA 1964, p13f; RENNER 1983, p395; OESER/SEITELBERGER 1995, p69ff, p76ff; BOURDIEU 1988, p786).

The notion of experience, however, is instantly linked with specific environmental contexts that have to be defined more precisely: In the first place, the child's immediate environment is the primary caregiver or mother (STERN 1995), and the family. Depending on specific socio–economic standards and cultural traditions it includes a mother, a father, siblings and grandparents. The family is a complex system of mutually interconnected relationships that shape the infant's development which, in her turn, again influences the family relationships (SROUFE/COOPER/DEHART 1996, p50). In the second place, the child's development is shaped by institutions (e.g., school), peer group relationships and the neighborhood (SROUFE/COOPER/DEHART 1996, p54ff).

This first context is itself embedded in a wider social and economic context which again is embedded in a specific culture (BRONFENBRENNER 1979). Culture as the all encompassing developmental context transcends all other contexts including the biological makeup of the individual. It is only consequent to acknowledge the important influence of culture on the formation of cognitive structures. Parents in every culture share the same major task in rearing their children. This inevitably includes the preparation of the children with the basic cultural standards of behavior in order to enable them to function as members of their specific society (WHITING/EDWARDS 1988). Therefore the individual has to be provided with specific cultural concepts that operate as maps of social reality and guidance of behavior (ARTIGIANI 1996, p7f).

In fact, the two factors—phylogenetic and ontogenetic—together build an emergent, inseparable entity that emerges in the individual developmental process (ROTH 1995, p29, p236f; OESER/SEITELBERGER 1995, p74). The developmental process again is influenced by environmental contexts whiten which it occurs. Thus, the ontogenetic development of the human mind and the cognitive system is structured by both the inner and the outer reality, genetic predispositions and natural/socio–cultural environment (ARTIGIANI 1996; COHEN 1994, p115, p192; TURNER 1992, p93; CARRITHERS/COLLINS/LUKES 1991).

Enculturation as the process of embodiment

In order to establish a theory of cognition that takes the context of self-organized socio–cultural systems into account, we have to concentrate on the process of the formation of cognition. The question we try to answer is what role the environment plays in this process. Anthropology provides an explanatory framework which focuses on the process of the embodiment of culture. Before we draw our attention to the process of enculturation, it has to be mentioned that a definition of the notion of culture is both crucial for an intelligible theory of cognition and rather difficult to establish since culture is by no means completely comprehensible in abstract definitions. Culture rather is a fluid set of structures that flow in inconceivable streams of diverse and distinct manifestations such as myths or artifacts. It is a system of representations expressed in symbols that transport specific meanings for the members of a society (GEERTZ 1983, p46). The difficulties of defining culture are reflected by the wide range of existing attempts (KROEBER/KLUCKHOHN 1952; WEISS 1987, p7ff). The similarity of the situation to the prior discussion about definitions is evident and provokes an ambiguous situation: We have to accept to work with an unsharp and dull defined notion of culture. In the same way this certainly may be seen as the main advantage of the whole concept of culture.[4] On that account, the notion of culture in this article is used in the sense of WERNHART's working hypothesis as everything that is created or constructed by man except the biological (WERNHART 1987, p21). This concept is already quite flexible, but as we will find out has to be modified for our purpose as well.

The process by which specific rules and values of a society are passed on to human infants is generally known as socialization. Yet, the notion neglects the importance of culture that encompasses the social, the family and the individual systems. Hence, anthropology changed the concept of socialization into that of enculturation. The notion implies both, the handing-over of a cultural system and the crucial role of culture for the ontogenetic process. Enculturation occurs not so much through explicit teaching and instructions but rather through the experiences of every-day-life, social interactions and the perception of socio–cultural reality (GADNER 1997; 1996, p98ff). In this connection we have to bring the relation and meaning of language and culture for cognition into context. Learning a language turns out to be one of the most important factors of primary socialization within which basic cultural schemas are ontogenetically embedded in the individual's mind (SHORE 1996, p237; ROMMETVEIT 1985). If we condense that point of interest, we may say that the individual's linguistic knowledge has a genetic as well as a social source, but whatever is specific to language is social (KLEIN 1996; OESER/SEITELBERGER 1995, p81; GLÜCK 1993, p573). In this sense VYGOTSKY emphasized the socio–cultural origins of even the most intimate and private aspects of speaking and thinking (LEONTJEW/LURIA 1964, p9f; SHORE 1996, p237).

Although language is not the only source that influences the development of cognitive structures, it is, nevertheless, a very fundamental part of cognition. The relation between individual, language and culture is one of the most complex and complicated phenomena: Language can be defined as product and by the same token as precondition of a specific culture (LÉVI-STRAUSS 1967, p81; GOODENOUGH 1971; BOURGUIGNON 1979, p206ff; CASSON 1981). Due to the similarity of the systems, language and culture are in all probability linked in the individual's mind (LÉVI-STRAUSS 1967, p75, p81; SHORE 1996, p237, p276f; KLEIN 1996), so that we may state that the child not only acquires a language but, beyond it, linguistically implied cultural standards. In fact, the child acquires a culture (SHORE 1996, p236ff; VIVELO 1981, p167f; INGOLD 1992, p695; LÉVI-STRAUSS 1967, p69; OESER 1987, p125f). Thus, acquisition of culture transforms the *precultural being* (VIVELO 1981, p167) into a mature member of society, who is capable of acting according to socio–cultural patterns of behavior and of functioning within the norms and rules of society (VIVELO 1981, p167ff; ARTIGIANI 1995, p141; LEVINE 1973, p61; BERRY/DASEN 1974, p133; OESER/SEITELBERGER 1995, p73ff, p79ff).

In terms of cognitive and neuro–scientific theories enculturation can be seen as the biological embodiment of environmental flows. In other words, enculturation is a process of interfusion that mingles macro-structures of cultural systems with micro-structures of human brains. The internalization of experiences produces and organizes patterns of memory. These so-called *engramms* correspond to genetically given structures and specific contents of learning and experience (ROTH 1995, p236f). *Engramms* are vital and therefore have to be durable and not dynamic, which logically means that they constitute cognitive categories which define what generally matters to be important and essential (GUTTMANN/BESTENREINER 1991, p112ff; ROTH 1995, p28f). This categorization is one of the most fundamental cognitive activities—it is the construction of *cognitive maps* which can be seen as equivalent to mental representations or enactions (OESER/SEITELBERGER 1995, p74; ROTH 1995, p28; VARELA/THOMPSON/ROSCH 1992, p176; ARTIGIANI 1996, p6ff). The active construction of neuronal networks corresponding to *cognitive maps* is a basic requirement for the encoding of distinct meanings (ROTH 1995, p28ff, p269). These are valid only in specific contexts which evolved ontogenetically out of an interaction between the individual brain and its socio–cultural and natural environment (ROTH 1995, p235ff, p297ff). *Cognitive maps* are patterns of connections of distinctive marks which codify relevant objects, circumstances, situations, etc.: *Cognitive maps* in fact represent the outside reality in the brain and lead the individual through her natural and socio–cultural environment (OESER/SEITELBERGER 1995, p74f, ROTH 1995, p28).

In this connection we understand outside reality to a high degree as socially and culturally constructed by actions and re-actions of the individuals as members of a society (BERGER/Luckmann 1966; HABERMAS 1981; BOURGUIGNON 1979, p198ff; WERNHART 1986, p124; TYLER 1986, p135; VARELA 1991, p105). Individual and society form a reciprocally dependent unity based on a network of interactions (WERNHART 1992, p28f; 1987, p24). Thus, the adult homo sapiens is both a natural and cultural being which makes it, after all, impossible to analyze the individual brain without taking its developmental contexts into account (GADNER 1997). From an anthropological standpoint the culturally determined differences between socio–culturally defined values and standards, contents of learning, and individual experience are undeniable (BOURGUIGNON 1979, p231; WHITING/WHITING 1975; CHILD/WHITING 1971; WEISNER/GILMORE 1977). The concept of VEMs (values, ethics and morals)—stored and transported in myths or equivalent media of socio–cultural memory—applied by ARTIGIANI illustrates the importance of socio–cultural information on the individual behavior: “VEMs are societal analogs of DNA: they excite people to act in ways that reconstitute the relationships, institutions, and behavior patterns defining particular societies” (ARTIGIANI 1995, p149). This kind of information guides the individual's behavior and thereby replicates the socio–cultural structures. In other words, abstract cultural systems have psycho–biological functions. This will be further elaborated below. For the moment it is sufficient to stress again that actions are based on emotions which themselves are channeled by external socio–cultural standards or factors like abstract concepts such as beliefs and myths. To put it in a more simplistic way we could say that people act on the basis of their beliefs. The importance of beliefs for individual behavior is again responsible for their social reproduction and the stability of intergenerational tradition (GEERTZ 1983, p261–288).

Seeing the world through cultural spectacles

As we have learned so far, ontogenetic development occurs in environmental contexts that are embedded in the individual's biological makeup. This leads us to state two important facts: On the one hand we can take for granted that learning determines the psychological development of the individual and thus her cognition. Anthropological research, on the other hand, shows that contents of learning and methods of socialization depend upon the particular culture. From these assumptions it is no more than a simple syllogism to conclude that cultural standards of thought, feeling and behavior are ontogenetically internalized and build normative cognitive patterns that are directly linked with the individual's biological expressions. The adult human being catalyzes his individually experienced perceptions and emotions through culturally defined standards and symbols (ARTIGIANI 1996, p8; RENNER 1992, p395; GOODENOUGH 1970, p104; TYLER 1969, p13; VARELA 1991, p99ff; ROTH 1995, p92ff; OESER/SEITELBERGER 1995, p79; OESER 1987, p124).

The formation of cognitive structures cannot be exempted from the interplay of biology and developmental contexts. The phylogenetic principles are no more—but also no less—than a flexible framework within which a socio–culturally structured individual ontogenesis takes place (OESER/SEITELBERGER 1995, p191; ROTH 1995, p236f; SHORE 1996, p16). Cognitive development continues until a relatively stable organization of mental attitudes, standards and patterns of interpretation of reality is constructed: This basic cognitive device is decisive for any further perception, cognition and behavior of the individual (COLE 1996, p7; BARNOUW 1973, p10; WHITING/WHITING 1978, p57ff; COHEN 1994, p115, p192; TURNER 1992, p93; BOURGUIGNON 1979, p218ff; ROTH 1995, p236f, p298ff). Consequently, we may characterize human consciousness, thought, feeling and behavior as embodied products of the socio–cultural development of the individual.

Closer examination will show, that these effects influence the development of cognitive structures immensely (SHORE 1996, p236ff). Konrad LORENZ (1973, p17) suggested that all higher levels of human information–processing capacities such as causality, substantiality or time and space are emergent functions of neurosensoric organizations that evolved as survival strategies of the species. The evolutionary approach is certainly right but, nevertheless, faces some limitations. It has again been anthropological research that challenged the sole concentration on the single factor of human phylogenetic evolution regarding the emergence of cognitive capacities. LÉVI-STRAUSS (1973), for example, described the variations of the causality principle throughout different cultures. All peoples code and classify their world in specific categories that organize every object according to specific systematizations. These are possibly based on causal principles and connections without any equivalent in European traditions (LÉVI-STRAUSS 1973, p20ff). Alfred GELL (1992) in his turn investigated cross-cultural time conceptions. His findings suggest that the notion of time is coded according to cultural variables. The concept is thus culturally constructed and represented in cognitive temporal maps.

These brief examples demonstrate how the definition of cognition as embodied action can be used very helpful for our purpose. Particular cultural schemes of interpretation of the world are ontogenetically internalized by the child through practices of socialization and daily life experiences of cultural reality. Through this process the individual acquires specific concepts to interpret reality and, moreover, what matters to be culturally defined as *real* (BOURDIEU 1988, p783f, p786; PARIN/MORGENTHALER/PARIN-MATTHEY 1971, p552). Children learn, so to say, *why things are the way they are* (BERGER/Luckmann 1966, p155; GEERTZ 1983, p270; SHORE 1996, p237). At this point we have to take into consideration the effect of a socio–cultural *common sense* on the cognitive system: Indeed we are forced to admit that we cannot precisely explain cognition without including the examination of *common sense* (VARELA/THOMPSON/ROSCH 1992, p150; VARELA 1991, p101). VARELA defines *common sense* as the individual's bodily and social tradition or history (VARELA/THOMPSON/ROSCH 1992, p150; VARELA 1991, p101). A more subtle paraphrase of that hybrid phenomenon comes from the cultural anthropologist Clifford GEERTZ, who regards *common sense* as a set of specific, historically constructed and defined standards of interpretation of experience which paradoxically relates the validity of these interpretations to the accuracy of the representations of reality it creates (GEERTZ 1983, p261–288). With CIOMPI *common sense* may be characterized as the average emotional state that comprehends all kinds of culture-specific (group-specific, family-specific, individual-specific) habitual patterns of thinking, acting and feeling (CIOMPI/WIMMER 1996, p41).

Hence we may infer that reality cannot be perceived *as it really is* but as we—as members of a special cultural tradition—have come to perceive it (GEERTZ 1983, p269f; ROTH 1995, p288; FOERSTER 1981, p58ff; STOLZENBERG 1981, p242ff, p291f). A WITTGENSTEINIAN metaphor describes this feature as an idea that seems like spectacles through which we perceive the world in a prestructured condition: "Das Ideal, in unseren Gedanken, sitzt unverrückbar fest. Du kannst nicht aus ihm heraustreten. Du mußt immer wieder zurück. Es gibt gar kein Draußen; draußen fehlt die Lebensluft.—Woher dies? Die Idee sitzt gleichsam als Brille auf unserer Nase, und was wir ansehen, sehen wir durch sie. Wir kommen gar nicht auf den Gedanken, sie abzunehmen" (WITTGENSTEIN 1952, §103).

In a way we may define the process of enculturation as the acquisition of specific spectacles. These embodied spectacles structure our cognitive image of reality. Thus, reality has to be defined as a (cognitive, cultural, etc.) construction (ROTH 1995, p278ff; SPRADLEY 1980, p6; CLIFFORD 1986, p10; BERGER/Luckmann 1966, p33ff; VARELA 1981, p306ff): "Während unsere Sinnessysteme vieles ausblenden, was in der Außenwelt passiert, enthält umgekehrt unsere Wahrnehmungswelt auch ihrem Inhalt nach sehr vieles, was keinerlei Entsprechungen in der Außenwelt hat. Dazu gehören scheinbar einfache Wahrnehmungsinhalte wie Farben und räumliches Sehen (Objekte in unserer Umwelt sind nicht farbig;[5] unsere Umwelt ist nicht perspektivisch aufgebaut, d.h. entfernte Objekte sind nicht klein). *Insbesondere aber gehören hierzu alle Kategorien und Begriffe mit denen wir die Welt (unbewußt oder bewußt) ordnen, alles Bedeutungshafte in unserer Wahrnehmung (die Ereignisse in der Umwelt sind an sich bedeutungslos), Aufmerksamkeit, Bewußtsein, Ich-Identität, Vorstellungen, Denken und Sprache.* Wir wenden diese hochkomplexen Konstrukte auf die Welt an, sie sind ihr aber nicht entnommen." (ROTH 1995, p232)

The cognitive categorization appears to be the point of intersection at which inner and outer reality fuse: Objects are not perceived as they really are but as a synthesis of object and cognitive category (ROTH 1995, p92ff; OESER/SEITELBERGER 1995, p79ff; LEONTJEW/LURIA 1964, p9; VARELA/THOMPSON/ROSCH 1992, p177). This phenomenon is generally known as cognitive condensation which helps to organize the complexity of perceived information (DAMASIO/DAMASIO 1994, p58; OESER/SEITELBERGER 1995, p78). The result of this cognitive reduction is a synthetically constructed model of reality which is structured by implicit linguistic characteristics and socio–cultural traditions (OESER/SEITELBERGER 1995, p78ff; ROTH 1995, p29; WHORF 1994, p12). In summary, context-specific integrated programs of feeling, thinking and behaving generated through action for all kinds of ontogenetically internalized patterns of social interaction form the essential structures of the psyche and the cognitive apparatus.

Conclusion, theoretical implications and consequences

As we have seen, substantial human capacities such as thought, behavior and feeling are subject to vast cultural influences. By the same token, the individual influences her socio–cultural environment and contributes to what we have defined as culture. Hence, the organism creates and affects the environment and at the same time is shaped by it. This circular and self-organizing process transforms the individual into a part of a socio–cultural network and the socio–cultural network into a part of the individual. BOURDIEU's two extensive studies—on the Kabylei society (BOURDIEU 1976) and on the social determinants of taste in France (BOURDIEU 1984)—have been crucial for anthropology concerning this point of interest. His 'habitus-concept' emphasizes the fundamental transformations of psycho–biological structures caused by cultural stereotypes, social learning and acting in specific interpersonal relationships. Habitus can be understood as an embodied system of developmentally structured dispositions of behavior, attitudes and ways to act that correlate with socio–cultural schemes of thought, perception and cognition (BOURDIEU 1987, p98f). On the basis of these studies it may be argued that the individual perceives the world corresponding to capacities and possibilities that are results of both, psycho–biological predispositions and socio–cultural contexts.

Regarding this multiplex interplay of factors within the development of cognition, the importance of interdisciplinary research should be acknowledged as the only possibility to gain satisfactory knowledge. In anthropology, for example, some of this knowledge is not new, but now we have the possibility of bringing together macro- and microcosmological processes. The central anthropological insight that cultural differences result from the process of enculturation may be interpreted in a different context: The study of cultural differences is itself some kind of biological study (INGOLD 1992, p694). As we have seen, cultural factors play a major role in the ontogenetic development of the individual and thus form her cognitive structures. Cognition consists of embodied patterns of categorization and interpretation within a particular context. Again the importance of a specific context has to be emphasized. We realize the interrelation between the body as "people's most fundamental mode of being in the world" (INGOLD 1992, p694) and a society/culture: "The practical skills of everyday life, language and speech, memory, perception and cognition—all these are developmentally embodied in the human organism: in its neurophysiology, its musculature, even in its anatomy. Cultural differences *are* biological. (By the same token, of course, biological differences are not—or at least *not* exclusively—genetic.)" (INGOLD 1992, p694).[6] The whole mental and psychic apparatus may in this sense be understood as a complex functional structure of biologically imprinted intrapsychic–subjective as well as interpersonal–social components of learning and experience (CIOMPI/WIMMER 1996, p41).

The concept developed in this article provides the outlines of an explanatory model of cognition which considers ontogenetical and phylogenetical, biological and socio–cultural, individual and interpersonal factors. Thus, a synthesis of anthropology with parts of neurological and psychological disciplines is necessary to explain this interrelation (FIRTH 1992, p217). As a main advantage, the concept developed above does not share any kind of cultural determinism due to its openness and flexibility. The future will bring new anthropological tasks such as the closer examination of perception and cognition, the analysis of learning and memory, and the study of intentionality and feeling, of consciousness and the unconscious as well as of the constitution of the self—topics which have previously been reserved for psychology (INGOLD 1992, p695). One could go so far to state that cognitive science will unavoidably become an anthropological enterprise (SHORE 1996, p8).

The theoretical framework developed in this essay clears the way for taking culture into mind and mind into culture (SHORE 1996, p317). Culture can no longer be separated from biology but has to be defined as the result of an interactive process between biological structures of the brain and socio–cultural functional patterns. These patterns are likely to be distinguished in orientational, expressive/conceptual and task models (SHORE 1996, p61ff). These models, in their turn, are mental representations of necessary and vital socio–cultural knowledge about the environment, which enable the individual to live and participate in her society/culture. We are finally about to state that the construction of *cognitive maps* correlates with the construction of socio–cultural models. Hence, cognition may be defined as embodied socio–cultural structures that transcend the individual's habitus and guide her behavior.

In that sense—and in addition to WERNHART's concept of culture—culture has to be defined as a set of mental representations or embodied models of socio–cultural reality as well as culture–specific patterns of thought and behavior. Moreover, it is represented in tools or artifacts and in other manifestations like abstract concepts, myths and legends. The author is far from claiming that culture is a purely mental phenomenon but it is, however, the individual human being that transports culture. Culture does not exist in a fluid external entity detached from living beings. Even cultural manifestations do not exist in vacuous space. On the contrary, culture is bound to living people who function as vehicles for it. On the other hand, embodied cultural maps are expressed by individual actions. The actions of two or more individuals are social interactions. Countless social interactions form an invisible network of crystalline structures that are referred to as culture. We have to recognize that nature and culture are mutually dependent on each other in homo sapiens.

The question of where the locus of *cultural knowledge* is supposed to be—located in the individual's mind, in the rules of society or in cultural artifacts—is a rather novel aspect of research work which demands an interdisciplinary approach (VARELA/THOMPSON/ROSCH 1992, p178f; SHORE 1996, p317). Maybe we are already in the position to state that it is situated in all of them together: Therefore, the concept of embodiment seems to be one possible solution to explain human psychic unity and cultural diversity.

It has been demonstrated in this article that the embeddedness of the individual in a socio–cultural whole matters especially for the formation of cognitive structures. At least human cognition is fundamentally linked to a socio–cultural context within which it develops ontogenetically. We may state that socio–cultural differences of cognitive structures and thus different modes of perceiving the world (as described by anthropology) do exist. No doubt, the formation of cognitive structures is based on the individual's biological makeup, but this itself is certainly influenced by specific environmental and developmental contexts. Different contents of learning as well as socialization practices result in specific organizations of psychic structures that effect different interpretations of the world in different societies/cultures. One could finally go so far to argue that the phenomenon of cognition is indeed social/cultural.

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Notes

1 In this connection the term anthropology implies different sub-disciplines as cultural or social anthropology, ethnography and ethnoscience or cognitive anthropology. An introduction and discussion of these disciplines is given in FISCHER (1992).

2 In this context the influential work of Margaret Mead and Gregory Bateson has to be mentioned.

3 KANT, I., Kritik der reinen Vernunft. 1787. Of course KANT's intention was to disprove the idea of pure perception as an idealistic invention.

4 "Vielleicht sind gerade die Bezeichnungsunsicherheit und Bedeutungsvielfalt des Kulturbegriffs eine Chance für die neue Programmatik der Kulturwissenschaften. Die Unschärfe des Begriffs ermuntert, nach den Gründen dafür zu fragen. Die gescheiterten Normierungsversuche unterstützen die Skepsis gegenüber normativen Wertvorstellungen. Die Vieldeutigkeit fordert zu hermeneutischen und historischen Analysen auf, die auch dazu beitragen könnten, die Hemmschwelle gegenüber der Auseinandersetzung mit komplexen Zusammenhängen zu überwinden" (SCHLESIER 1996, p35).

5 Cf. GUTTMANN/BESTENREINER (1991) p34ff, VARELA (1991), p102f, VARELA/THOMPSON/ROSCH (1992) p157ff.

6 In this connection the studies of Mary DOUGLAS (1966; 1970) have to be mentioned. They analyze the mutual relations of body and society within different cultural contexts and concluded that the biological body of the individual is transformed into a social body. The distinction between two types of individual bodies is obviously linked with a specific construction of a body image which exerts influence on the body habitus. Thus, the whole body of a mature homo sapiens is the product of its phylogenetic evolution and its ontogenetic development within a specific socio–cultural context.

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Paul C. Kainen

Mathematical Cognition

Abstract

Mathematical cognition occurs in a veridical fashion even though it is implemented biologically. Why is this possible? It is argued that all cognition is in fact mathematical and a metamathematical model is proposed. Cognition is claimed to be based on facts as emergent self-references. An approximate cycle is the reification of the concept and it is required to have finite parameterization. Perception takes some evanescent, poorly monitored event involving a quasiperiodic dynamic and approximates it with a regularly modulated cycle. As with the visual perception of LISSAJOUS *figures, a closure algorithm is required to parse amorphous, infinite-dimensional reality into some finitely parameterized oscillation. This depends on parameters given to the closure algorithm.*

The job of cognition is to predict how the cycles influence one another and what new cycles will be produced.

A cognitive system is a triple consisting of finite sets of facts and interactions and a category of representation. Facts are perturbed cycles and are completely described by a finite set of parameters. Moreover, because the facts themselves are determined by the closure algorithms which depend on controls, the facts you get are the ones you want.

Interactions between cycles can be interpreted within many different categories. Examples are given where cycles are linked topologically, geometrically and algebraically. The latter leads to a binary model for a special case of cognition, which gives a quantifiable advantage for intelligent selection.

Key words

Cycle, closure, self-reference, error-correction, parameterized approximation, intelligent selection, biological computation.

If ONE BELIEVES THAT biological skills have evolved to accomplish biological ends, it is paradoxical to observe the success with which cognition applies to mathematics. Why should tools designed to improve human performance of tasks within physiologically and socially defined roles be capable of correctly developing mathematics?[1]

Suppose that, in fact, cognition is itself mathematical in origin (even though it manifests as neural activity in humans). Then one would not be surprised to find that it applies to abstract realms.[2]

This idea is shocking since it would claim that mathematics applies directly to *us*. Yet we know that mathematics does apply to physics, and with remarkable success. As we (and all biology) involve the iteration of purely physical processes, in a highly organized fashion over space and time, why should not the mathematical regularities appear in amplified form? Instead of averaging out, the physics is focused to accomplish biological action needed for survival so there is surely no *a priori* reason to discard the possibility that mathematical regularities can arise within cognition, perception and various organically-defined realms.

Mathematical modeling for any aspect of biology is impossible if one accepts the view of NIETZSCHE (as quoted in DEMPSEY 1997) that both logic and mathematics depend on suppositions which don't correspond to reality, such as the idea "that there are identical things or that a thing is identical at different points of time." And surely biology, much more than physics, cannot support such a strong uniformity hypothesis since variation is so basic to all known living processes.

But the view that mathematics requires exactness is simply wrong. In fact, there are results which work quite well under assumptions of error, noise and bias. Not just probability and statistics but many other fields of structure and computation have theorems that remain true under various perturbations of theory or data.[3]

We have termed the collection of mathematical results which hold in spite of variation *robust*; consequences are discussed in KAINEN (1999). Not only can "robust" mathematics obtain results which aren't invalidated by small errors in distance measurement, it can obtain similar results for a notion of dimension based on orthogonality and applies also to results of BIRKHOFF and KOLMOGOROV-ARNOLD-MOSER related to dynamical systems.

Biological computation must pass other tests as well such as speed, accuracy and parallelizability. It should be possible to develop a theory of cognition with these heuristic features (WIMSATT 1997; KAINEN 1997).

Having a model for cognition (even if it is the wrong model) can be helpful in that leads one to pose particular questions. The answer to some question may show that the model is not correct and even indicate a path for improvement. Also, as in the theory of feedforward neural networks (KAINEN 1998), an oversimplified and not exactly correct model can lead to a quite useful mathematical and computational perspective.

An advantage of quantitative models is that they can be falsified. In the process of constructing experiments to test the model's predictions, one can also be led to ask new questions of the underlying phenomena.

So let us now accept the idea of a mathematical model for cognition and see where it leads.

Cognition and self-reference

WEBSTER's Seventh Collegiate Dictionary defines "cognition" as "the act or process of knowing including both awareness and judgement."

Our thesis is that cognition can be mathematically modeled in such a way that its properties emerge because there are specific theorems to permit their propagation. Further, we argue that the objects of cognition (i.e., the facts) are precisely the self-referents and that these are emergent in the sense that they are provably not contained in any closed system.

Consider the problem of self reference in cognition. Well-established mathematical results, due to GÖDEL, TURING and RUSSELL, all show that self-reference is not possible in a closed system. Here is a plausibility argument: If referencing itself can matter to a system, then the model of the system must differ to reflect the self-referencing. But this means that the model has to be forever enlarged to reflect the iterated referential process.

However, if the system is not closed, then one can have self-reference; this is just what one wants for a biological model. So we shall consider how the mathematically pristine notion of cognition which we have advanced above can be implemented in biology.

Let us define a *cognitive system* as three interlocking structures: A set of facts, a set of interactions, and a categorical calculus in which the facts and interactions are interpreted. Thus, the calculus provides a computational substrate. It appears possible that there are not too many distinct useful calculi and that when two cognitive systems share a common calculus, their interactions can produce a larger cognitive system.

We shall not burden the reader with a technical description of category theory, agreeing with THOM (1991) that the details overwhelm a basically simple idea. A category is a structure consisting of *objects* and *morphisms*, like the nodes and arrows of a directed graph, with a multiplication which is only defined for certain pairs of "composable" morphisms. In addition, it allows us to formalize the casual constructions of set theory, making the foundations much more rigorous.[4] As one would expect with such a general notion, very few theorems apply. However, those that do (such as the adjoint functor theorem) should apply to cognition. See KAINEN (1991).

In biology, "facts" include biochemical cycles, neural firings, cellular replication, biomolecular oscillations, population fluctuations, etc. Each of these notions is self-referencing. Further, the interactions have highly regularized aspects, including spatial and temporal periodicities. For example, one could consider the predator–prey cycle (THOM 1977).

Categorical models

Any mathematical category in which we can model the network of facts and interactions includes its own form of self-reference. Self-reference can be thought of as the process by which internal and external data are distinguished. Describing this can be done, at least in principle, by category theory. This leads to the notion of special categories called *topoi* which give a coherent account that subsumes logic and geometry. A technical feat which might be compared with this is a combined model for electromagnetism and the nuclear forces. To push the analogy further, a topos is a model of the (mathematical) universe prior to and during the Big Bang. As with microphysics or cosmology, the theory of topoi involves a reconsideration of "elementary" notions like "point in a set".

Our idea is that cycles constitute a more durable form than the isolated point. A cycle, qua geometric object, can be moving through some larger ambient space, while along the cycle (i.e., varying the phase) there is a higher-amplitude spot. More generally, two curves can intersect with moving curves producing a moving intersection. Thus, points could arise via the interaction of facts (a rather LEIBNIZIAN conclusion). For an interesting transformational duality somewhat of this sort, see MOWITZ/GOUDSMIT (1989), and for the idea of a cyclic topos, see THOM (1991).

Thus, the topos can be sophisticated. On the other hand, it is limited by what can be done. There are only four division algebras over the real numbers, for example, so there are really only four natural choices for the variables of an arithmetic calculus. Up to the current era, only the first two have been investigated.[5]

Formal mathematics is not the only way in which the topos can evolve. Art and literature are powerful, though idiosyncratic, methods for exploring self-reference. For example, the work of M. C. ESCHER refers to the geometry of space, while PYNCHON'S novel, "Gravity's Rainbow", contains a narrative MÖBIUS band. Works like these can change the implicit assumptions which everyone (even mathematicians) uses to reason about the universe.

One has a nearly closed cycle in mathematical conception with emergent properties—true but not provable in the original system. We progress by adding on new assumptions motivated by intuition. This is the experimental aspect of mathematics (so much like evolutionary "tinkering", POLYA 1954).

But the mere fact that we still don't know whether the laws of arithmetic are internally consistent does not prevent us in the slightest from using them effectively. The machine seems to work whether we believe in it or not.

Cycles as the self-referents

A basic sense of our notion of "fact" is that in order to have an influence, it must be dynamic, persistent and retain a characteristic form. Hence, the fact must be approximately cyclic. Self-reference is a nearly closed cycle *and* the process of closing it: a sentence, not just a noun or verb.

Requiring something like a cycle is quite natural—and indeed, the vast repertoire of biological periodicity supports a cyclic view: from circadian rhythms in the mitochondria to 90 minute dream-cycles in adults. Further, since self-reference is constantly changing (both mathematically and in the biological sense), the notion of variable cycle—both in frequency and form—captures a surprising depth of biological veridicality.

Biology needs well-coordinated, cyclically varying resources; as we now know, active structures descend at least to the level of molecular motions. Could the full information be completely coded in structure? If not, where does the information come from?

The notion of cycle permits one to quantify the way in which adding a new cycle alters existing system parameters (e.g., by adding a new generator to a homology group and, thus, changing a BETTI number). It is also robust to most small perturbations, as any model for biological processes should be. Indeed, the lack of exact closure caused by internal and external changes in the dynamics of a system allows error correction to provide information on the combined effect of change.

Mathematical theory should determine the maximum perturbation which can be tolerated without extinguishing some cycle, leading to predictions for homeostasis and experimental test.

Let us agree then that a *fact* is a mathematical object which is a nearly closed cycle. Cognition will then be modeled by a particular calculus that applies to the mathematical domain in which the facts and their interactions exist. Recognition of the cycle amounts to "awareness", while measuring the distortion needed to close the cycle is the "judgement".[6]

MATURANA and VARELA's idea of *autopoiesis* is somewhat related to our idea of self-reference except that we propose specific mathematical procedures. Our models also permit appropriate interactions between facts as we now discuss.

Interactions

Facts may interact via topological, geometric or algebraic criteria depending on the category chosen. Choice of category plays a role rather like choice of context, and it is easy give examples where two cycles will mutually reinforce or constrain one another depending on the category.

Take two circles in three-dimensional space, one passing through the disk spanned by the other. That is, imagine that the cycles are *physical* objects like a magician's rings which are *linked* (in the sense of knot theory). Indeed, knots were used by the Mayans to record astronomical information, and their application has been considered by KAUFFMAN (1987, p107), (following R. D. LAING) in terms of human relationships.

On the other hand, each circle might be traced by a rapidly rotating point. If the frequencies associated with the two rotations were identical, two linked cycles might reinforce or cancel through resonance—

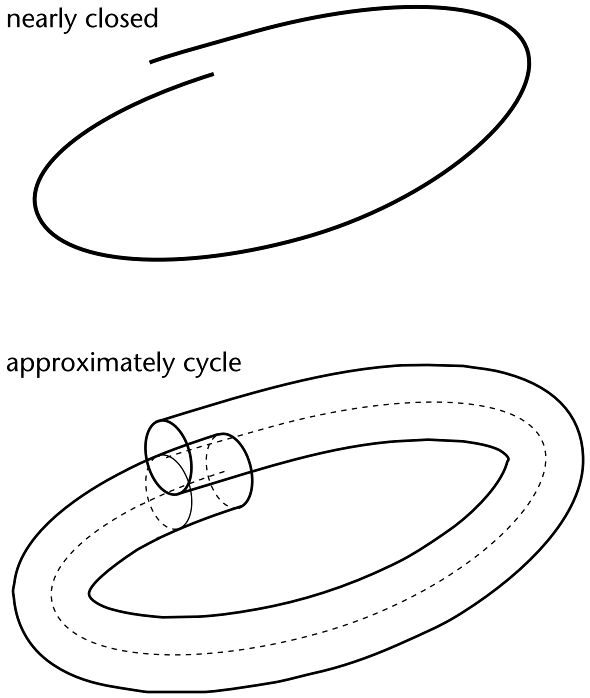

Figure 1: Thickening a nearly closed cycle produces an intersection manifold, which contains an exact cycle.

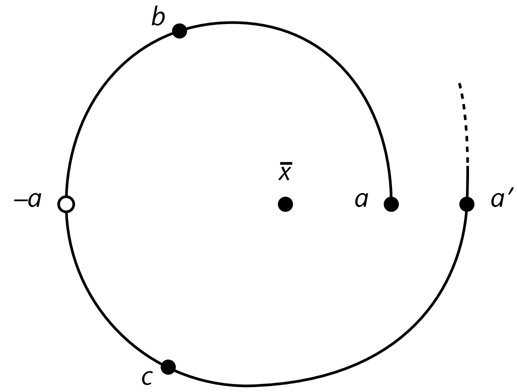

Figure 2: A curve which begins near x-bar, wanders away and then returns.

like tuning forks. It is, in fact, known that there are quite exact phase-correlations between widely separated areas of the brain.

We shall also be interested in *algebraic* linkages between cycles in a special model of cognition. When a cycle is interpreted as a composition of morphisms, we call it *commutative* if the composition is the identity function. Sometimes the commutativity of some of the cycles can force commutativity in others and this is what we mean by an algebraic interaction.

Cycle closure

Just as the world coheres for us from a "blooming, buzzing confusion" (in W. JAMES' phrase) into an intelligible script in which we play a role, so must the organism make sense of its environment. How are the computations to be done so that a complicated curve is replaced by a closed cycle with some simple parameterization?

It is necessary to have a *closure algorithm* (see Figs. 1–5). For instance, a gap of, say, 1 micron (a millionth of a meter) would be ignored by typical human closure. However, more careful testing (with different control parameters) would quite likely detect the gap. Thus, the result of a closure algorithm depends on the internally given constraint parameters as well as the external problem data.[7]

How can the cycle itself emerge from the curve? One way is to imagine that the cycle takes on thickness, so that it is now a snake which nearly (but not quite) swallows its own tail. Unlike the reptile, however, the fattened cycle can intersect itself and it is not too difficult to show that within the overlap of the fattened cycle there is a narrower cycle which corresponds to a coil. And that is what the eye does see when one enlarges the scanning dot in a corresponding visual display.

The human sense of vision does quite a good job of fitting cycles to data as demonstrated by the perception of LISSAJOUS figures.

A LISSAJOUS figure is most easily understood in two stages. First, one considers what happens when two periodic forces act upon an object and their periods are harmonically related as a ratio of small integers. For instance, imagine two circular motions of equal rate but opposite clockwise sense. The forces will cancel twice and reinforce twice. Thus, the sum of the two complex cycles 1, *i*, –1, –*i* and 1, –*i*, –1, *i* is 2, 0, –2, 0 so in the equal amplitude case, one gets a line of double the amplitude. The angle which this line makes with the *x*-axis is determined by the relative phase of the two cycles.

When any other situation holds, then the two cycles produce a resultant cycle which is two dimensional. For example, if the two cycles have relative rates 2 : 3, then they produce a five-pointed star-shaped figure which has rather rounded corners (see Fig. 6).

In order for such a LISSAJOUS figure to be visible to us the underlying scanning rate has to be at least 20 or 30 Hz, and more for a complex figure. Visibility of the figure is not, however, just persistance of vision. In a second stage of understanding, one continues to perceive the same topological form which seems

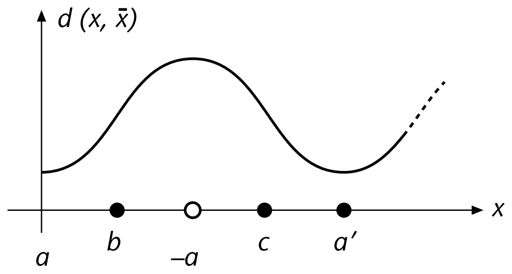

Figure 3: For points x on the curve, graph of distance of x from x-bar as a function of the arc-length of the curve from x to a. For the curve of an almost closed cycle, this distance may vary quasiperiodically.

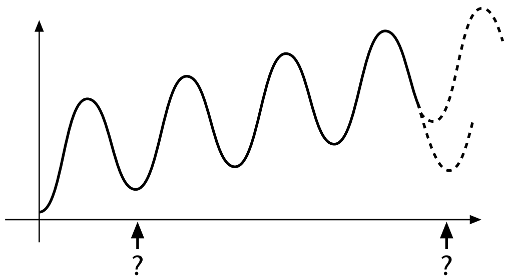

Figure 4: The behavior of closure algorithm will depend on memory. Based on this distance graph, an algorithm which can wait five cycles to establish pattern would be able to avoid surprise.

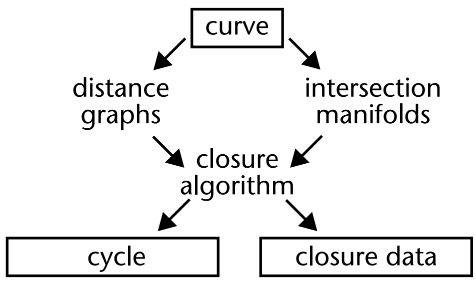

Figure 5: Raw data (the curve) is first transformed into mathematical models (distance graphs and intersection manifolds). Based on its internal parameters, the closure algorithm acts on the mathematical data to produce two outputs for the system: a closed cycle and a finite set of parameters which describe dynamical variation of the cycle required for closure within the tolerance constraints given to the algorithm. Mathematically, the cycle (which may be knotted or linked) carries topological information while the movement and distortion parameters are of a geometric nature.

to move and bend when there are minor disturbances in the component oscillations (see Fig. 7). [8]

Indeed, not only can one easily name the ratio which produces a displayed simple figure, human vision can approximate quite complex curves by LISSAJOUS figures which are tumbling and stretching in phase and amplitude modulation. Such capability of imagining coherent motions in a modulated LISSAJOUS figure provides concrete proof–of–principle for visual cognition.

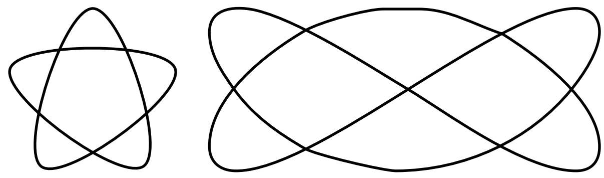

Figure 6: These LISSAJOUS figures are determined by the ratio 2 : 3

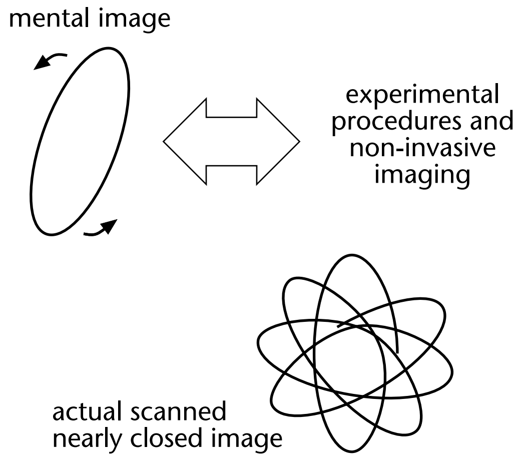

Figure 7: Psychophysics and computational neurophysiology could be used to study the processes of mathematical cognition.

Binary cognition

Now we shall consider a special type of cognitive system which may be relevant for artificial intelligence and logic. To describe the system, the reader will need to consider a few mathematical ideas in somewhat greater detail. However, the motivation for our effort is an interesting "economies of scale" result which shows how hierarchical increases in the complexity of cognition may take place.

A *hypercube* $Q(d)$ is a graph defined for every integer $d \geq 0$ by a simple inductive construction: $Q(0)$ consists of just one vertex and no edge (also called the "trivial" graph). For any $d > 0$, take two disjoint copies of $Q(d-1)$ and add a new edge for each vertex in $Q(d-1)$, joining it to the corresponding vertex in the other copy. This is simpler than it sounds; for example, $Q(1)$ is the graph that consists of two vertices and one edge connecting them; $Q(2)$ is a square (i.e., the four vertices and edges in the square's boundary). Joining corresponding vertices of the square gives $Q(3)$, the corners and edges of the ordinary cube. Note that $Q(d)$ has 2^d vertices and $d \cdot 2^{d-1}$ edges (see Fig. 8).

One can identify the vertices of $Q(d)$ with binary strings of length d so that two vertices are adjacent

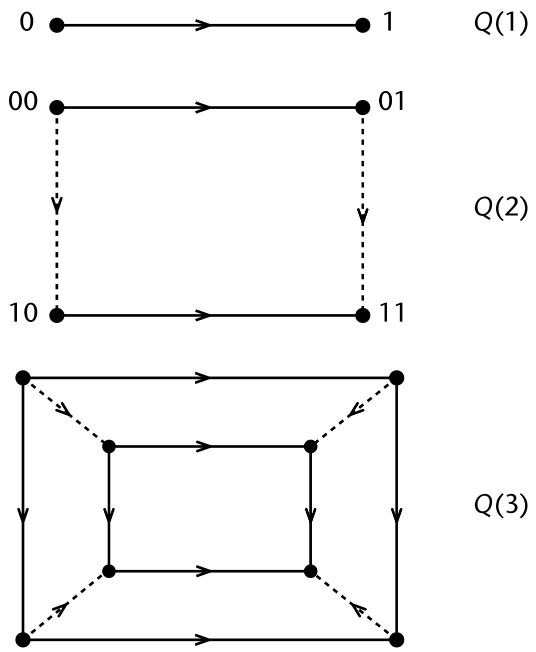

Figure 8: Hypercubes have a simple inductive construction.

(i.e., joined by an edge) if and only if the corresponding binary strings are identical except for exactly one coordinate. For example, in $Q(5)$, the vertex (10110) is adjacent to (11110). This provides us with a natural way to assign direction to the edges, so that the initial vertex of the edge has the 0 while the terminal vertex has the 1. A directed edge is also called an *arc*. Hence, we can regard the hypercube as a directed graph (called the HAMMING cube in view of Hamming's work on information and binary coding).

If C is a category, then a *diagram* in C is a directed graph $Q(d)$ where the vertices are represented by objects and the arcs correspond to morphisms. A *cycle* is any sequence of arcs such that the terminal vertex of each arc is the initial vertex of the arc following it in the sequence, with the first arc following the last arc. A cycle in a diagram *commutes* if the composition of its morphisms is the identity. The length of a cycle is the number of distinct arcs it contains. (This is like the topological property that each cycle is the boundary of a disk and so is unknotted.) A diagram commutes if every cycle in the diagram commutes.

These conditions are rather more special than we need but easier to describe and sufficient for our purposes since we now consider only those categories in which every morphism is an *equivalence* (i.e., has a a two-sided inverse). Such categories, called *groupoids*, arise naturally within quantum computing which uses only invertible operations.

We can look at individual commutative cycles as facts, and the commutativitiy of an entire diagram as a higher-order fact. In some cases, it is not necessary to consider every cycle in order to show that a diagram commutes. For example, $Q(3)$ has 6 distinct cycles of length 4 corresponding to the six square faces of the cube, and there are 15 distinct cycles of length 6. However, the diagram can be shown to commute if any five of the six square faces commute. (This is called the "cube lemma".)

The computational advantage grows rapidly with the dimension d of the hypercube diagram but we must select the facts to check so that each one corresponds to a square face on the "side" of the hypercube. (Each edge of $Q(k)$ gives rise to such a square face in $Q(k + 1)$ and if all of these square cycles commute for $k = 1, 2, \ldots, d - 1$, then $Q(d)$ also commutes.) For example, there are approximately ten trillion cycles in $Q(10)$ but one need only check 4097 of them to show commutativity.

As the dimension of the cube increases, the efficiency of this cognitive procedure increases exponentially fast. For there are $n!(n! - 1)/2$ cycles of length $2n$ in $Q(n)$ (where $n! = n(n - 1)(n - 2) \cdots 3 \cdot 2$ denotes factorial), while $1 + (n - 2)^{2n-1}$ square cycles are sufficient to check.

An additional use of this argument, due originally to EHRESMANN, shows that naturally equivalent diagrams (all of the side squares commute and the morphisms between corresponding objects are equivalences) have identical commutativity. Facts in one are facts in the other.

Cycles in psychology

When a child reaches a certain age, PIAGET has noted that particular skills of quantitative reasoning become available. Pouring a liquid from one glass to another shape does not fool a child who can recognize volume constancy. But this is exactly the realization that, if poured back into its original container, the liquid's level would remain the same as it had been. Hence, the skill amounts to detecting that the molecular trajectories would on average be cyclic.

In therapeutic interactions, analysts have reported that periodicity in bipolar disorder can be an indicator of treatment success. Moreover, to the extent that chaotic regimes can permit the transition from one structure to another, the

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moment when the patient recognizes the closed pattern he has been creating and wishes to change it affords an opportunity for the analyst in PALOMBO's theory. Defense mechanisms, at the other extreme, amount to circular responses, designed to reinforce one another at the slightest external provocation.

Note that a single cycle can be self-linked. This just means that the cycle may be knotted. Perhaps such phenomena occur in consciousness, and for somewhat similar reason as they do in DNA. There is a tremendous compression when the extremely long strands of this molecule are wound and coiled in a superdense packing (COZZARELLI 1992).

From a therapeutic standpoint, the "coils of consciousness" must be briefly cut and rejoined in order to allow access to some buried moment. In living tissue, the topoisomerases make cuts and joins that allow the transcription of information. Perhaps these cycles can even be chaotically tangled.

Applications

Since we are talking about an abstract thing, a mathematical system, rather than some anthropomorphized operation on thought, cognition appears in many realms.

For example, visual cognition occurs in the selection of objects of visual attention and the control of the 4 Hz saccadic eye movements. Artists have shaped some aspects of visual cognition (KANDINSKY 1926/1979).

Human vision makes a good domain for research since many capabilities are little understood. An instance of this is *color-constancy* which is achieved when even extreme variation of external lighting does not extinguish the ability to name particular colors.[9]

More subtle processing also exists. It is known that color and form follow separate neural channels and it is easy to recall examples from the fine arts which show that a loose, approximate application of colorful touches superimposed on a figure drawn of ink will cause without effort the colors to adhere to their proper places on the figure. But development of such higher-order visual (or musical) cognition may require substantial experience and be subject to cultural bias.

Cognition may appear in movements of physical coordination by athletes and martial artists (or cats!). A goal of the "artificial intelligence" community is to produce a cognitive system, not just a passive machine. In contrast, we also now are trying to learn whether the ecology has capabilities of adaptation which can tolerate (or not) various human-originated effects.

Biological cognition involves a stream of facts, exogenous and endogenous to the organism, interacting through various mathematical media. The stream is cyclically oriented but changes over time through the dialectic between physical entropy and the organic process. Evolution is the fact that a local synergy of the two influences exists and is approximately stable—except for occasional periods when there are radical and discontinuous changes in the cycles themselves, (for instance, during periods of widespread extinctions).

The applicability of cognition to evolution would explain much more easily than does current theory such phenomena as the apparent development of complex organs of sensing according to a limited set of feasible engineering plans. Further, cognitive evolution is consonant with the evolution of cognitive (at least occasionally) beings.

Knowledge of the cyclic structures of the organism will provide a new logic for medical therapy. Some beginnings have been made recently regarding a time-regimen based on determination of individual rhythmic states. If this could be determined for cancerous tissue, perhaps treatments could be timed for both maximal patient tolerance and minimal tumor tolerance.

We conclude that the evolution of epistemology, from knowledge of a point to knowledge of an approximate cycle, reflects a natural progression from physics to biology and could have relevance for philosophy and natural science.

Notes

1 We say "correct" in the sense that the corresponding science produces testable hypotheses and tangible technology. See POINCARÉ (1905/1952, p. xxiv).

2 There is an old dichotomy within mathematics between those who hold that we deal in a PLATONIC realm of abstract forms and those who postulate a critical role for human mentality. I see no conflict between these two theaters—for human passage among the celestial spheres is hard-fought and fleeting.

The mathematicians, POINCARÉ (1905/1952) and HADAMARD (1954), wrote of the role of intuition and the teeming subconscious in the creation (or recognition) of mathematical emergence. Fortunately, my goal is much more modest than theirs. All I wish to convey is that there is a sea and that fish swim in it, while they were showing, in particular, how they go about finding the fish and catching them.

3 For example, it can be shown that any mapping from an ordinary finite-dimensional euclidean space into itself which has the global property of never changing distance by more than some fixed constant is everywhere within a small

multiple of the fixed constant of a linear isometry. See HYERS/ULAM (1945). (This is now known to hold even in infinite-dimensional spaces.)

4 Category theory provides a unifying framework for mathematics. For instance, a partially ordered set (i.e., a transitive, anti-symmetric relation) corresponds to a category in which there is at most one morphism between two objects, while a monoid (i.e., a binary operation with identity and obeying the associative law) corresponds to a category with only one object. The monoid is a *group* if each morphism is an equivalence.

5 Recall that a complex number is a pair (a, b) of real numbers (corresponding to the point $a + bi$ in the usual notation). Addition is coordinatewise but the rule for multiplication is $(a, b) \cdot (a', b') = (aa' - bb', ab' + a'b)$. Hence, $(0, 1) \cdot (0, 1) = (-1, 0)$ so $i^2 = -1$.

The step from stage 1 to stage 2 of the topos has been essentially synonymous with the complexification of physics. This occurred because of quantum mechanics, though the need for complex variables was also recognized in electronics and optics.

In going from the real numbers to the complex numbers, one loses the unique linear order. Differentiability becomes much more difficult in the sense that a complex function has one derivative if and only if it has them all. Arnold has remarked also that, when the variables are complex, boundaries of submanifolds do not separate the space. Algebraically, the complex numbers have the nice property that polynomial equations necessarily have solutions.

Moving from complex numbers to quaternions, removes the commutativity of multiplication; order now matters. The octonions are 8-tuples of real numbers with a non-associative multiplication. But this gives the octonions the ability to carry superimposed information which depends (like DNA transcription into codons) on how they are processed.

We believe that eventually biology will require a topos that utilizes all four of these possible developmental stages.

6 Perhaps a more general notion than cycle will prove interesting to consider—as it has in topology.

Two topological spaces are *homeomorphic* if it would be possible to continuously deform one into the other. (This intuitive "rubber sheet" definition can be made rigorous.) A cycle is homeomorphic to S^1, the unit sphere in the plane, which is the set of points in the euclidean plane with distance from 0 (i.e., *norm*) exactly equal to 1.

A "generalized fact" (or *scenario*) is a set of points on the surface of a sphere in some possibly infinite-dimensional space. The set of points need not be finite but should satisfy an analogous topological property called compactness.

For instance, consider a finite, statistically independent set of random variables, all uniformly distributed in a unit ball in n-dimensional euclidean space. One can show that the variables are almost surely extremely close to the unit sphere (points of norm 1), once n is sufficiently large. Thus, such a random sample would become a scenario.

Various facts can be derived about a scenario. There is a shortest HAMILTONIAN cycle (with respect to some measure of distance) that passes through all of the points. Alternatively, one can order the points so that the norm of the partial vector sums is kept as small as possible. This amounts to minimizing the diameter of a polygon, or equivalently, to minimizing the chance of overflow in an adding machine by choosing a "smart ordering" of the data. See KAINEN (1993).

7 An obvious parameter is the radius of the cross-section; one could also impose conditions on radius of curvature or smoothness. Thus, various sorts of parametrized approximation could be applied to obtain closure. A heuristic method could keep track of local minima, with a threshold for sensitivity and a finite bound on memory.

8 In studying these optically displayed figures of resonance, LISSAJOUS, a 19th century French physicist, was preceded by BOWDITCH, the 18th century American navigator, and followed by others such as HUMBOLDT. LISSAJOUS, however, seems to have been the first to notice the psychophysical aspects of the imputation of quasi-physical reality to the recognized form—as though it had been etched in glass on a rotating cylinder. (Actually, this is not quite enough since with a proper display device one can perceive also distortion in a wire–frame–like image.)

9 Since regions are colored, rather than individual points, we may reduce to a cyclic model by considering the boundary. Another clue for a cyclic model of color perception is the way in which the micro-order of on/off white-light events is interpreted in a particular way as "color" in illusions such as the Butterfield Effect (used to produce color commercials when television was still only black and white!); see WINFREE (1980, p17).

One color-constancy experiment showed that a particular form of brain damage (only involving connections between the two cortical halves) prevented successful naming of colors. Hence, there is much processing that must be done to determine color from the stimulation levels at the rods and cones.

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Søren Brier

The Cybersemiotic Explanation of the Emergence of Cognition

The Explanation of Cognition, Signification and Communication in a Non–Cartesian Cognitive Biology

Abstract

LORENZ and TINBERGEN created a theory of innate cognition and communication based on a new and very differentiated evolutionary theory of motivation. Although LORENZ struggled with encompassing the emotional basis of instinctual cognition in his theory he was not able to transcend the traditional objectivistic stance of science. The Danish ethologist REVENTLOW has shown that it is not possible for behavioral science completely to separate subject and object in the cognitive process. REVENTLOW coined the new concept a "rependium" to describe the sudden reorganization of the perceptual field when an animal 'sees' a phenomenon as 'something'. But he did not manage to make a general theory of the self-organization of cognition. In order to deal with these paradoxical issues, I turn to the new cybernetics of BATESON where "information is a difference that makes a difference" and the later development of this theory in MATURANA and VARELA's theory of autopoiesis and VON FOERSTER's second order cybernetics. But even they are missing a true theory of signification. Such a theory is provided by C. S. PEIRCE's triadic, evolutionary, pragmatic, realistic and objective idealistic semiotics. I show how to combine these two theories and WITTGENSTEIN's language game theory in a non-CARTESIAN transdisciplinary pragmatic cognitive science crossing the animal-human boundary.

Key words

Cybersemiotics, autopoiesis, biosemiotics, non-Cartesian cognitive science, ethology, signification, rependium, second order cybernetics, sign games, animal cognition, instinctual cognition.

Introduction: Ethology as an entrance to a Non-Cartesian Cognitive Science

A true scientific theory of information, cognition and communication has to encompass the area covered by the social science and humanities as well as biology and the physio–chemical sciences. A true transdisciplinarity is necessary if we want to understand information, cognition and communication in natural, living, artificial and social systems in a broad based scientific theory. To find a way to connect the phenomenological view from within with a theory of behavior and language is crucial for such an enterprise—a theory of signification.

We are looking for at theory which is on the one hand not mechanistic and on the other hand not subjective idealistic or vitalistic. This was actually what LORENZ and TINBERGEN set out to make when they created the science of 'ethology' beginning in the 1930es based on the three foundations of modern biology: The theory of evolution, the ecological theory and modern population genetics plus the method of comparative anatomy transferred to instinctive movements (LORENZ 1970–1971).

In the present paper I want to further develop the epistemological framework of ethology and evolutionary epistemology in the light of the problem of establishing the reality of qualia in a materialistic evolutionary cognitive biology and from there theoretically be able to connect to the semantic level of meaning in human language communication. Epistemologically we cannot—when working from an evolutionary basis—continue using the naive realistic epistemology of logical empiricism in combination with rationalism and atomistic mechanicism that LAKOFF (1987) calls *objectivism*.

What is interesting and fruitful about LORENZ's biological theory of animal behavior is the attempt to make a cognitive science based on biological theory surpassing on the one hand the reductionism based on mechanisms of physics and chemistry and on the other hand the vitalism of DRIETSCH and others. Both LORENZ and TINBERGEN were aware that animal instinctive behavior is primarily inherited. A good theory of genes was not available at the time but heredity was well known and supposed to have a material basis in the chromosomes and population genetics was under development. Morphology was well studied and since DARWIN it was being studied from the angle of survival value of animal behavior. One of the puzzles was how animal instinctive behavior and learning could at the same time be hereditary and purposeful. There was no doubt that animals had a selective perception and related to certain events as biologically meaningful to their survival when they appeared in certain situations depending on the animals mood. But neither LORENZ or TINBERGEN managed, in my opinion, to formulate the needed integrative evolutionary–ecological theory for cognitive science that could be an alternative to the objectivism of modern cognitive science and its information processing paradigm (LAKOFF 1987, BRIER 1992, 1996 b).

A very important conclusion in LAKOFF (1987) is that our biology is decisive for the way we formulate concepts and make categorizations. He further points out that linguistics lack a theory of motivation to understand how we extend metaphors from the concrete to the abstract in a meaningful way and to explain how we organize concepts into different type of categories. He points out that cognitive models are embodied, or based on an abstraction of bodily experiences, in the way that many concept properties are motivated by bodily or social experience. This is the way they make sense thus providing a non-arbitrary link between cognition and experience that is not logic in the usual way we understand it. This means that human language is based on human concepts that are motivated by human experience. It is simply easier to learn something that is motivated than something that is arbitrary or logically arranged. So one of LAKOFF's conclusion is that motivation is a central phenomenon in human cognition. This fits very well with ethological thinking, but unfortunately its very physiological and energy oriented models of motivation, cognition and communication are not developed enough to encompass the area from animal instinctive communication to human linguistic behavior. A further development in evolutionary epistemology is needed that focus more on psychological and communicative aspects.

I start my search for a non-CARTESIAN foundation for a science of cognition, information and communication by reflection over the work of the Danish ethologist Iven REVENTLOW, who—on the basis of LORENZ and TINBERGEN's theories—attempted to uncover a common basis for ethology and psychology to create a true GALILEAN psychology[1]. REVENTLOW's idea (REVENTLOW 1954) was to make a cognitive science on a bio–psychological and behavioral basis and he managed to the start formulating new concepts but never found an adequate foundation for a behavioral model of cognition and communication. I show that BATESON (1973) and later the new second order cybernetics of VON FOERSTER has developed some concepts on the self-organization of cognition that seems to conceptualize what REVENTLOW was looking for. Further the concept of autopoiesis and structural couplings of MATURANA and VARELA developed in the same tradition of biology based cognitive cybernetics brings us important steps forward. But I also show that these are not enough to explain the function of how meaningful communication is possible. To this end I turn to integrate concepts from PEIRCE's semiotics which as the same time offer an alternative philosophical foundation to mechanistic materialism on one hand and pure constructivism on the other in the form of a realistic objective realistic evolutionary philosophy. But lets start with a short description of the emergence of the ethological paradigm, its goals and its development.

A selective historical summary of the ethological science project

The original point of departure for discussing the cognition of living systems and what we can learn about our on epistemological situation from that was the Christian view of the world as created in a meaningful pattern where God and Satan fought each other. But to fight paganism especially the nature oriented religions and superstitions Christianity more an more conceived of nature as 'dead'. In the vitalistic view introduced through the inclusion of ARISTOTLE's view on nature in the Scholastic theology the pan-psychic elements was played down. Only animals was seen as having Entelechy instead of possessing souls. This way they had no rights to the sacraments and a seat in Paradise (or Hell). But they were given divine instincts to help them survive without knowing themselves what they were doing in Gods great plan (BRIER 1980).

As natural sciences developed after the Renaissance the concept of nature became more and more mechanized. DECARTES finally declared both plants, animals and the human body to be machines. One of his followers, MALEBRANCHE, started comparative psychology with experiments that did not acknowledge that animals could feel pain. Later LA METTRIE and LOEB developed at detailed background for mechanistic explanation of animal and human behavior (BRIER 1980).

In the 19th century the idea of evolution spreads from the social sciences to geology and finally biology. LAMARCK is one of the founders of the biological science as he is seeing the living systems as a 'stream of life' with one common beginning separating it from the physical–chemical aspect of nature by a qualitative difference. A discipline of 'natural history' develops, but this biology do not obtain the status of a science. It is DARWIN that lay the foundation for a more scientific evolutionary biology in the middle of the 19th century and also contributes to the foundation of ethology through his book *The Expressions of the Emotions in Man and the Animals*. Late in the century Ernst HAECHEL founds the ecological idea. The evolutionary and ecological thinking coins the basis for the new ethological explanations of the nature of and the forces behind animal behavior supported by the later development of population genetics (BRIER 1980).

Actually an evolutionary physics is also created in the same century through CARNOT, KELVIN, and CLAUSIUS' thermodynamics which later gets a statistical interpretation by BOLTZMANN. A unified concept of energy is also developed. Thermodynamics inspired both LORENZ and FREUD when making models of the energies of the psyche in animals and man. LORENZ (1950) launches his psychohydraulic theory of motivation. It is based on a concept of action specific psychic energy that accumulates until the pressure is to big and it goes of by very low stimulation or even spontaneous. FREUD in his early 'Entwurf' treats the nervous systems nearly as a steam engine where psychic energy is behaving as steam accumulating in a steam engine until it forces its way out (ANDKJÆR OLSEN/KØPPE 1986). FREUD has a kind of energy model for the Id. Psychic energy from the basic drives, such as sex, can only be suppressed for some time. Sooner or later it will force its way 'out' and then often in neurotic behavior. The first law of thermodynamics says that the amount of energy is constant. Energy cannot be destroyed but only transformed. LORENZ developed his psychohydraulic model for action specific psychic energy (motivation) as an attempt to understand the many different kinds of motivations or moods in each species, and to understand how those drives that seem to 'dam specific urge' for an instinctive behavior such as mating or hunting. Later LORENZ (1966) in 'On Aggression' also launches this model for the aggression drive (BRIER 1980)[2]. In *The Backside of the Mirror* LORENZ (1973) discusses a new the relation between instinct, motivation and learning and realizes that there must be some kind of phenomenological reward in the form of pleasurable emotions making the animal want to do a particular behavior again. He has problems with the nature of appetite behavior. It has to include emotions, some kind of an awareness of a goal and the fulfillment/reward. So the psycho–hydraulic model seems not to be enough in explaining what goes on. Although LORENZ in the 50's had a neutral monistic theory of the mind, so he acknowledged that their would be a psychological side to the physiological described phenomenon of drive, he did not ascribe causality to the psychic functions per se. But now it seem that one had to ascribe some causality to psychological processes beyond what could be described in the physiological models at that time. One seems to have to choose between a cybernetic model of a goal seeking machine with feedback or the intentionality concept coming from phenomenology as non of them seems sufficient for a scientific understanding of cognition, information and communication we have to look for a framework and a model that will encompass them both in a fruitful way that is neither mechanistic—which the classic, or first order cybernetics still is—nor subjectivistic giving the animal human awareness and conscious intentions (BRIER 1992, 1993a).

It is clear to LORENZ that emotions has functions and survival value. WIMMER (1995) gives a further development of this kind of science about emotion which one can also find in a cybernetic version in BATESON's (1973) work. But the problem is that it is still a purely functionalistic description not really able to explain how certain things and event becomes significant for the living system in such away that they attach signification—i.e., see them as a sign for something emotional, existential and vital for the self-organized system (BRIER 1992). The Danish ethologist and psychologist Iven REVENTLOW has made some interesting and thorough analysis here that can bring us an important step further in the analysis.

Reventlow's Theoretical and Methodological Background

REVENTLOW's master dissertation is from 1954 (REVENTLOW 1954). One sees clearly in all his works that the major divisions in psychology according to him at that time are behaviorism, gestalt psychology and psychoanalysis. Added to this is a respect for phenomenological studies—via phenomenology of the Copenhagen school—and for experimentation. Although REVENTLOW has placed most emphasis on experimentation and methodology he has always been keenly conscious of the importance of remaining aware of his theoretical background. REVENTLOW's fascination with the emerging biological science of ethology, was unique in Danish psychology. By incorporating a gestalt psychological perspective and a respect for the epistemological depth of statistics (rare in an empiricist), he has used the TINBERGEN experimental observation tradition to develop approaches that have infused comparative psychology with new dimensions and depths.

REVENTLOW's objective is to examine, as precisely as possible the complex phenomena of 'everyday life' in situations as natural and simple as possible in order to find meaningful 'basic units' of behavior which can be used as 'fixed points' in the analysis of more complex psycho–biological phenomena such as the human personality. REVENTLOW's training actually focused on the psychology of perception, but his desire to achieve a greater exactitude and objectivity in psychology has led him to psycho–biological behavioral research.

The transition from humans to experiments with vertebrate animals—mostly sticklebacks—was the first simplification undertaken by REVENTLOW—done, because it is easier to work and experiment with animals. Also in animals, the personality factor (individuality) does not have such a dominant influence on the release and control of behavior as it does in humans. Although animals do have individuality, the general characteristics of behavioral release and control are not concealed by them as they are in humans. The less complex the organism one works with, the less the individuality will dominate and 'mask' the general aspects of behavior. On the other hand, to ensure that the results are relevant to human psychology, the animals used in the experiments must have an individuality factor strong enough to be included as an inevitable factor when attempting to construct general models of the functional organization of behavior.

At this point one might expect that REVENTLOW would have thrown himself into experiments with rats and pigeons for which there is a time–honored analytic tradition in psycho–biological behavioral research—especially in its development in the United States in the area of comparative psychology and behaviorism. But REVENTLOW has several reasons for rejecting this approach: firstly, his greatest interest lies not with 'arbitrary learning' but with the emotional/motivational foundations, the basal 'unconscious' processes that govern much of our behavior relevant to developmental psychology and psychoanalysis/psychiatry. Secondly, he wishes to work with behavior in 'everyday life' and with surroundings 'natural' for the organisms' behavioral repertoire. He does not believe that the psychological experiments done within behaviorism normally fulfill this condition. The behaviorist thinks that by having a cat press buttons in a 'puzzle box' it is possible to ascertain something of importance about its behavior, but "no one could reasonably expect to achieve an understanding of EINSTEIN's thoughts by observing his behavior while he was attempting to solve a very simple cat problem such as catching a mouse in the dark with his bare hands." (REVENTLOW, 1954, p5). This is of cause a difficult problem for humans. Furthermore REVENTLOW points out that biologically the white laboratory rat must be viewed as an artificial product (1970, p46) (my translation from Danish): "A living physiological specimen, 1) whose reactions, compared to the wild rat, are relatively independent of emotional factors, 2) which to a great degree is lacking social behavior 3) which is not very aggressive or anxious 4) which is relatively unaffected by pain and 5) which has an unbelievably small need for mobility,—altogether an exceptionally well-adjusted laboratory guinea pig which can be placed together with fellow members of its species in a very small space, but which on the other hand certainly bears very little resemblance to a wild rat. There remain only rudiments of the wild rat's strength, aggressiveness and social behavior. LEVINE and MULLIN's […] conclude that the growth environment of the laboratory rat is so protective that the rats do not develop a complete endocrine system. What we have here is, all in all, an emotionally rather blunted 'personality' compared with the 'wild type'". (REVENTLOW 1970, p46)

Finally REVENTLOW points out that, judged in relation to his purpose of finding basic functional laws of psychology, the effort by the behaviorists to simplify the experiments as much as possible has led to working with far too few forms of motivation; e.g., hunger, thirst and avoiding pain. Working with so few basal motivations, we can hardly expect to learn anything essential about the animal's behavioral individuality. In sum, one can say that the comparative psychologists' and behaviorists' oversimplification of experimental designs has been a step in the wrong direction if you wish to study normal motivational and functional organization.

Reventlow's final choice of experimental animal and situation was male sticklebacks tending their nests. A wild species with its own natural microcosm in the laboratory. It is obvious that insights into the learning processes as such are extremely important in understanding the emergence of the individual's behavioral individuality. But in all probability it is at first most expedient to work with behavior types in which the learning process does not cast too much of an individual–historical veil upon the motivational structure of behavior. This is significant seen in the light of our general ignorance regarding basic structures of behavior which somehow must determine what is learned. It is well known that we learn only that which we are motivated to learn—or need to learn as a matter of survival. Lorenz (1973) also argued in favor of the existence of many more types of learning processes than the behaviorists normally work with. He has argued that the characteristics of these types are to a high degree determined by the nature of the basic motivational structures which are their starting points.

If one wishes to include the organism's 'behavioral personality' systematically in one's models of the functional organization of behavior, then learning processes exclude the execution of reproducible experiments with the same organism. If we roll the results of all the experiments done on different individuals into an average, the individual character's importance to the process disappears, and at the same time the uncertainty as to the value of the results as 'general' laws increases. It was for this reason, among others, that Reventlow instead thought it important to start by analyzing the functional organization of instinctive reactions. Reventlow's work during 1970–1977 aims at finding new and more fundamental concepts of psychobiology (the modern concept would be 'cognitive science') culminating in his 1977 paper, where he launched his new 'rependium' concept about the sudden shift in the 'construction' of cognition, to see something as significant.

The 'Rependium': The construction of a fundamental Galilean concept in psychology

In 1977 Reventlow reached his first concrete attempt to "…continue Lewin's endeavors to restructure psychological concepts by analyzing phenomena of apparently different types so as to create a basis for the formation of new concepts reflecting their purely theoretical/functional properties—without undue consideration of their psychological context. The following will serve as an example of how one can work toward finding psychological concepts of a more functional abstract type than those used today. Many psychological concepts are just concepts borrowed from the conceptual world of everyday life…" (p130)

In this attempt to go beyond the normal surface dualism Reventlow is very much in line with systems theory and cybernetics. In this 1977 article he sums up observations taken from ethology, phenomenological psychology and gestalt psychology which inspire him to formulate a deeper concept:

1.Reventlow's first example is a condensation of three major ideas and observations:

a. He makes a comparison of the ethological concept of sign stimuli with the general gestalt principles (e.g., laws of proximity, equality and the good curve). He offers a common psychological interpretation of sign stimuli as species–specific gestalt principles whose function, unlike the common gestalt principles, is dependent on motivation. If an animal is not especially motivated to mate, more sign stimuli of a stronger nature are necessary to trigger reaction.

b. Reventlow argues for applying the concept of sexual sign stimuli to humans based on Reventlow (1972). They can possibly explain why people possessing a strong unreleased sexual urge experience objects and movements normally not associated with sex as being sexually laden. Psychoanalysis uses the term sex symbols, e.g., when a sword or a candle is seen as an erect penis.

c. But the common element which Reventlow wishes to emphasize arises from a third observation he made during his work with sticklebacks: When a highly motivated male is shown a female dummy with a low release value (having few sign stimuli) it may swim about for a while and then suddenly react with its characteristic courtship swim (a zigzag dance) followed by prolonged reaction to the dummy. This phenomenon—presumably a sudden lasting alteration of perception—can be seen also in the experience of gestalt figures and phenomena that have acquired the nature of sex symbols.

2. The second example is also taken from ethology, namely the so called imprinting, especially known through Konrad Lorenz' experiments with geese and ducks (Lorenz 1935). By presenting himself as the first mobile object in the duckling's life and thereby releasing a pattern of behavior which after a brief period becomes irreversible, he was able to induce the ducklings or goslings to follow him

everywhere, totally ignoring their 'real' mother. REVENTLOW sums up and concludes on the restructuring of perception through meaning:

"The classical concept of imprinting differs from the usual learning processes in five ways:

a. By occurring very quickly (e.g., the time it takes a duckling to follow an object for 20 meters).

b. By requiring only a single exposure and a single reaction by the animal.

c. By occurring only at a certain period in the life of the individual. By its stability after just one occurrence—it can reasonably be termed irreversible, and

d. By carrying no other reward than the reaction itself. Imprinting is very important for the individual's later social behavior—not to mention the choice of sexual partner and 'social circle'. Imprinting can be compared to the process that occurs when one looks at a drawing where at first we only see a meaningless jumble of dots, splatters and lines and then suddenly perceive a 'meaningful' figure. In other words a sudden restructuring of the area of perception into a meaningful figure." (REVENTLOW 1977, p132).

3. The third example consists of the so-called kipfigures or double figures, one of the best known examples being 'Rubin's vase', where we see either a vase or two human profiles. What distinguishes these phenomena from the above mentioned is their reversibility. It is rather like having two equally 'strong' alternatives which thus are interchangeable. However, as in the previous example, there is always one alternative that takes precedence over the others at any given moment.

4. KÖHLER's (1927) monkeys are the fourth example. By a sudden flash of insight they realized that the sticks they had climbed for fun, could be used to reach a coveted bunch of bananas. The chimps combined three different forms of behavior (instinctive, 'trial and error', and insight) in one action. Similar 'ah–ha! experiences' of sudden insight are known from numerous animal and human experiments and points to the establishing of new perceptual meaningful structures. REVENTLOW writes: "It is evident from DUNCKER's studies that as soon as a person achieves insight, the individual elements that are of relevance to him are integrated in a totally new and stable structure." (REVENTLOW 1973, p134)

What REVENTLOW wants to find and what he actually suggests is a common 'mechanism' or psycho–biological function, which makes all these different phenomenon happen. REVENTLOW's conclusion is: "What do the phenomena described above have in common? As far as I can see they share the significant feature that as they emerged a radical change occurred in the relations between various phenomena in the psychological field. This change was brought about through a discontinuous and at times irreversible process leading to the formation of a new and stable structure where all previous elements are simply effaced."

As far as I can se REVENTLOW is here on the tract of the establishing of what MATURANA (1983, 1988) calls a structural coupling and, as we shall go into later, what PEIRCE calls the establishing of semiosis. REVENTLOW gives the new functional psychological concept a name: "Let us […] call this phenomenon a 'rependium' (from Latin 'repente' = the sudden unexpected)—a term that will hopefully make it easier to handle in conjunction with the many other gestalt phenomena.

By the term rependium we are to understand creation through a sudden and discontinuous process of an unforeseen, stable structure which is a decisive departure from previously existing structures which have now, from a psychological viewpoint, vanished."

A part of the world emerges as something meaningful to the animal. The reaction is not mechanical. The 'stimuli' often has to be presented several times before for instance a stickleback 'reacts'. Further it has to be in a certain motivational state. This implies that motivation is not a simple physiological concept e.g., HINDE (1970). It cannot be explained on the physiological level although it has physiological aspects (see BRIER 1992 for a further analysis).

In our discussions on these topics REVENTLOW has admitted—like LORENZ(1973) saw it to—that the rependium function presupposes mental ability. This means that even a stickleback must be ascribed intentionality and cognitive experiences. So REVENTLOW seems to be in the same difficult situations as LORENZ. They both start their study of behavior from a rather neutral monistic world view where matter and mind are in two different sides of reality. But their evolutionary world view forces them into a theory of continuation between the mental capacities of human and animals and to consider mental awareness, emotions, and intentionality as having survival value (or else they would not exist). REVENTLOW (1970) sees—and it is clear from ethology's concept of sign stimuli—that the living system within environmental constraints creates its own 'Umwelt' (as von UEXKÜLL calls it). This seems to indicate that we have to leave a mechanistic view of evolving matter (BRIER 1993b). Further REVENTLOW's analysis points to that we have to leave the logical empirist

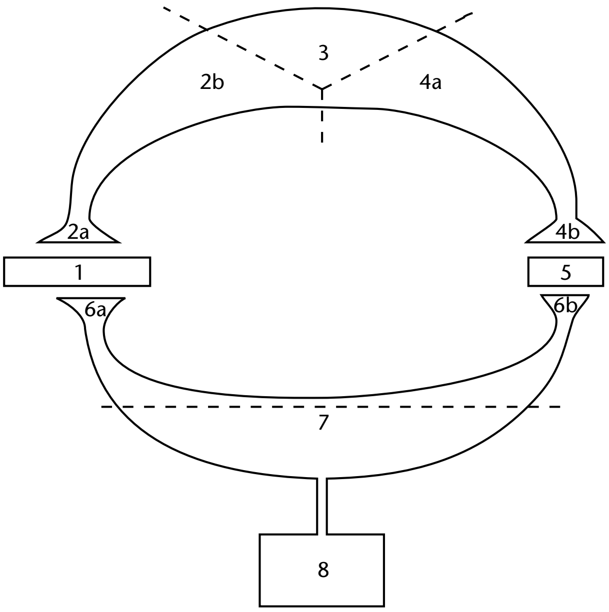

Figure 1: "[…] illustrates the conditions for observation of an individual organism. 1 represents the exterior world, which stimulates/perturbates both the observed individual as well as the observer. 2, 3 and 4 represents mechanisms in the observed individual, which cause that 5, which represents the total exterior behavior, is brought forth. 6a and b represent the sense organs of the observer, and 6 c the other perceptual parts of the nervous system and what further determines 7, which is his experience of the observed behavior. 8 represents the description of the observations which the observer gives, and which becomes the scientific datum, that is the foundation for the further scientific analysis […] When 6a is not situated symmetrical with 2a is it because animals most likely some times react on stimuli, whose physical properties we do not know […], while we (e.g., through physical measurement apparatus) can get knowledge about appearances of the physical world, that are without significance for the perceptions of animals. In the same way 6b is smaller than 4b and 5, because the animals have behaviors which we do not know, and even some that we cannot perceive or measure yet." (REVENTLOW 1970 p32 translated from Danish)

epistemology of science (often rather closely tied to the mechanistic ontology) (BRIER 1995). REVENTLOW sums up his methodological problems in the following model (Figure 1), which can be viewed as an illustration on some of the basic problem second order cybernetics is an attempt to overcome through the concepts of circularity and constructivism.

In his further analysis of the problem of the scientific observer REVENTLOW points out, that the main problem is not only how to determine the relation between 1 (exterior world) and 5 (exterior behavior), but also to determine the relation between 2a (the animal's perception of the world) and 6a (the observer's perception of the world), and the relation of this relation to the relation between 5 and 6b (observer's perception of the behavior of the animal). One of the problems is that we do not have any final knowledge about 1 and 2a. Second order cybernetics is built on the acknowledgment of the circularity of this problem.

According to REVENTLOW's methodological results we never will have such a final knowledge in causal deterministic terms. A certain kind of creative construction seems to be going on within certain limits. This result reflects back on the relation between 1 and 6a. Within certain limits we also construct what we see. We know that this phenomenon is partly built into ours and all living systems cognitive system, partly triggered in sensitive periods and partly learned through childhood and part of it is caused by scientific training (paradigms and so forth) and that it has survival value.

The crux of the matter is the problem of the relation of motivation, intentionality and feelings to the cognitive level. No functionalistic model of explanation of behavior, perception and communication can account of the willings and emotions of the minds of animals and man so far. This is also crucial in the discussion of what information is and what the foundation of information science should be. The foundation of meaningful experience categorization and communication is the crucial question in this discussion that cognitive science should solve as for instance LAKOFF (1987) points out so strongly.

If one looks at LORENZ development of his theory this is what he is struggling with conceptually (BRIER 1980). Motivation cannot be modeled in mechanical terms. He then uses an energy or psychohydraulic model which promote the idea of some emotional energy which has to be released. This is very close to FREUD's way of looking at things and I actually think that ethology is deepening FREUD's concept of the Id and can explain more how projections, which make you see thing as symbols, can happen. But still the models do not go deep enough into the nature of motivation, intentionality and emotions.

On one side we have the information theory of SHANNON—which in WIENER's cybernetics is connected to thermodynamics. Added to that are the idea of artificial intelligence and the functionalistic cognitive sciences. Today united in 'The Information Processing Paradigm'.

On the other side we have existential philosophy, phenomenology, hermeneutics and semiotics. These are the traditional arts of meaning, signification and mediation. They are the traditional humanistic disciplines of interpretation and cultural consciousness.

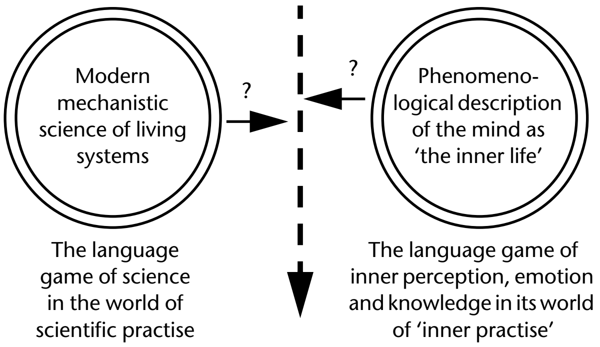

Figure 2: The mechanistic and phenomenological description systems isolated from each other and blind to each others conceptual worlds.

Cognitive information sciences partly based on first order cybernetics has run into a powerlessness situation in their attempts to find the algorithm's of intelligence, informational meaning and language. This structural approach has great problems with the phenomenon's of context and signification and how they interact. They want to understand every thing including consciousness and meaning algorithmically (LAKOFF 1987).

The 'binding problem' as a situation of powerlessness calling for a second order view

My point is that what is in modern brain and consciousness research called the 'binding problem' between matter and mind in the brain, and what we have called the relation between the functionalistic view and the phenomenological, is an example of a clear paradox in a scientific program. When science are confronted with paradox it is time to broaden the philosophical foundation to be able to develop new concepts to deal with the empirical finding, as BOHR (1954) points out.

In my opinion the problem is that one is trying to combine two phenomena which are conceptualized in two different knowledge systems. That they reside in two different description systems means that the exist in two different worlds which *are blind to* each other. See figure 2 for an illustration.

The problem is that the reductionistic materialistic or even physicalistic paradigm have no scientific concept of mind which include emotions and qualia and the phenomenological approach describing individual mind content from within, have no concept of matter. We will have to construct a conceptual framework that can create a knowledge system in which both description systems exist so they will stop being blind to each other. Then we may create a language in which they can speak to each other (see figure 3).

Can we place the two types of description in the same world? To do this we must have a look at both descriptions and there foundation. The scientific description is primarily a product of the western culture and the 'inner world description' is most highly developed in the eastern culture diffusing into western culture through PHYTAGORAS, PLATO and later developer's of this theory as PLOTIN and ST. AUGUSTIN, popping up again in the great Catholic mystics of the middle-ages and in the Renaissance in a newPLATONIC mysticism which again situate man in the center of the world. But later the development of the natural sciences has instead put the mathematical 'laws of nature' in the center of the world and man as just one product of evolution among many. The 'inner view' has survived in European phenomenology, existential and hermeneutical (Continental) philosophy from KIERKEGAARD through HUSSERL to HEIDEGGER, GADAMAR, SATRE, MERLEU PONTY and the late WITTGENSTEIN. This tradition has so far not made any important impression on the study of brain and behavior of organism. Second order cybernetics seems to be one of the few traditions that have taken 'the inner view' up in a biological although still functionalistic tradition.

Second order cybernetics bio–constructivist framework

As an example Heinz VON FOERSTER (1986) has evolved some very interesting thoughts about the dual evolution of biological system and the world it computes. It is closely related to MATURANA's idea of the co-evolution of autopoietic system and environment, but it has an interesting epistemological and ontological turn and it carries on with REVENTLOW's problem, how organism carve out of realities of the Universe through evolution. "The dual interdependence of organism–environment per-

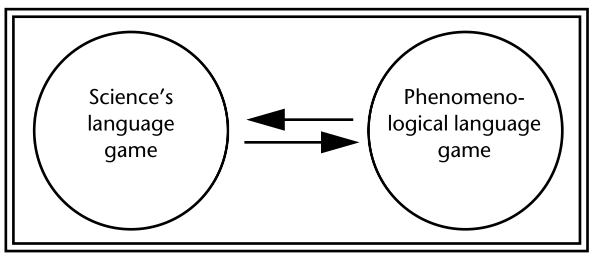

Figure 3: Common conceptual framework for science and phenomenology making communication possible.

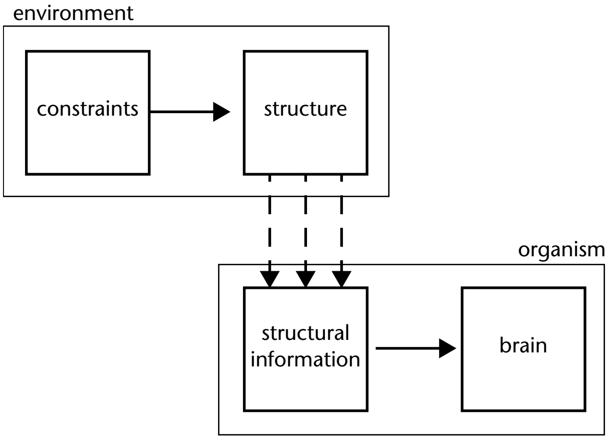

Figure 4: Information flow in the organism-environment (O-E) system.

mits a dual interpretation of the tree of evolution [...] Instead of interpreting points on this graph as *species of organisms*, one may interpret them as *species of environments*. Thus viewed, this cart represents the evolution of environments that were successively carved out of the physical universe. These environments evolved from simple, almost deterministic ones, to extremely complex ones, where large numbers of constraints regulate the flow of events. [...] Figure [4] sketches the circular flow of information in the environment–organism system. In the environment constraints generate structure. Structural information is received by the organism that, in turn, computes the constraints. These are finally tested against the environment by the actions of the organism." (VON FOERSTER 1986, p83)

So as in the physical theory of general of relativity we cannot speak of an absolute time or absolute space we cannot in VON FOERSTER's bio–psychological theory of cognitive systems talk of an absolute reality/environment. Both theories still retain the idea of one Universe, although it seems to bee something of a KANTIAN 'Thing in itself'. In this situation it seems useful as DREYFUS/DREYFUS (1995) to use HEIDEGGER's distinction between a 'Universe' and a 'World': "A set of interrelated facts may constitute a *Universe,* like the physical universe, but it does not constitute a world. the latter, like the world of business, the world of theater, or the world of the physicist, is an organized body of objects, purposes and skills, and practices on the basis of which human activities have meaning or make sense. To see the difference one can contrast the *meaningless* physical *universe* with the *meaningful world* of the discipline of physics." (DREYFUS/DREYFUS 1995, p435)

So you might conclude that the universe is not a reality, but a metaphysical construct made by theories produced in our scientific worlds. But these theories are again based on the cognitive skills we have developed in evolution which guarantee their survival value. They have a shared basis with most of all the other Vertebrates. VON FOERSTER (1986) goes from this type of argument to a theory for the understanding of how the development of a common world happen through communication:

"Look again at Fig. [4], which represents the information flow between a single organism and its environment. Because symbolization requires at least two interacting subjects who are immersed in an environment that is common to both, we must extend this diagram to admit a second subject. This is done in Fig. [5]a.

Subjects S_1 and S_2 are coupled to their common environment E. In contrast to Fig. [4], in which the organism is faced only with an environment with given constraints, now each of these subjects is confronted with the additional complication of seeing his environment populated with at least one other subject that also generates events in the environment E. Hence S_2 sees, in addition to the events generated by E, those generated by S_1, and because these take place in E, they shall be labeled E_1; conversely, subject S_1 sees in addition to events generated by E those generated by S_2, which will be called E_2. Thus, in spite of the fact that both S_1 and S_2 are immersed in the same environment E, each of these subjects sees a different environment, namely, S_1 has to cope with (E, E_2), and S_2 with (E, E_1). In other words, this situation is asymmetrical regarding the two subjects, with E being the only symmetrical part.

Assume that E_1 and E_2 are initial attempts by S_1 and S_2 to communicate environmental properties to each other. It is clear that these attempts will fail unless—and this is the decisive point—both subjects succeed in eventually converging to like representation for like universal features. This process may be expressed symbolically as in Fig. [5]b. The arrows indicate the convergence process, and E_0 stands for the final universal 'language' spoken by both subjects. At this point the initial asymmetry ceases to exist and both subjects perceive the same environment (E, E_0).

As in all evolutionary systems, the outcome of this process cannot be predicted in the usual sense, because the goal that established equilibrium is not

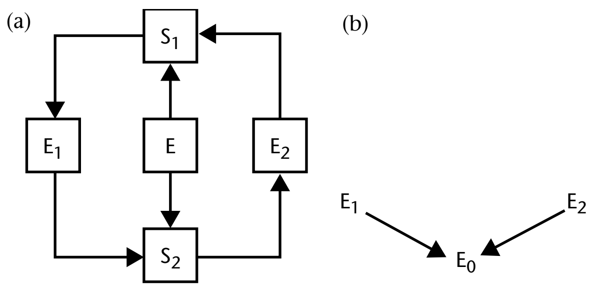

Figure 5: (a) Communication system including two subjects S_1 and S_2 generating (linguistic) events E_1 and E_2 in a common environment E. (b) The convergence progress to a common 'language' E_0 indicative of successful communication.

directly apparent in the final equilibrial state, which is a communicable symbol, whereas the goal is *communicability."* (VON FOERSTER 1986, p87–88)

This epistemological foundation of second-order cybernetics connects it with important points in HEIDEGGER's phenomenology. The important point from HEIDEGGER is that as an observer we are always already a part of the world when we start to describe it. We cannot have a—what LAKOFF (1987) calls an 'external realism'—but only an 'internal realism', as we are *in* the world. Our science works from within time and space as PRIGOGINE/STENGERS (1986) points out. When we start to describe it, we to a certain degree, separate ourselves from the wholeness of the world of our living praxis. A great part of our communication and thinking is not of our own doing. It is biological evolution and cultural history which signifies through us, and as Karl POPPER points out history cannot be given a deterministic lawful description.

MATURANA has—in the same line of thinking as VON FOERSTER—pointed out that there is an ongoing interaction between the autopoietic system and its environment. They co-evolute in a historical drift (non-deterministic). Organisms who live together become surroundings for each other coordinating their internal organization, and finally languaging is created as coordinations of coordinations of behavior. So there is a complicated psycho–biological development and dynamic system organization behind cognition and communication. The aspects of the processes of mind, which can be modeled in classical logical terms, do not seem to have any special position or control of how the intentions, goals and ideas of the system are created. Further the elementary processes of which this system consists do not seem to be made of classical mechanistic information processing, but out of a self-organized motivated dynamics.

Peirce's semiotics used on ethology

In ethology one says that ritualized instinctive behavior become sign stimuli in the coordination of behavior between for instance, the two sexes of a species in their mating play. So—as it is already in the language of ethology—a piece of behavior or coloration of plumage in movement becomes a sign for the coordination of behavior in a specific mood, as mating for instance. It is the mood and the context that determine the biological meaning of these signs, which are true triadic sign seen from PEIRCE's triadic and evolutionary semiotics. Here is one of PEIRCE's sign definitions from an unidentified fragment from *Collected Papers*:

"The easiest of those which are of philosophical interest is the idea of a sign, or representation. A sign stands for something to the idea which it produces, or modifies. Or, it is a vehicle conveying into the mind something from without. That for which it stands is called its object; that which it conveys, its meaning; and the idea to which it gives rise, its interpretant. The object of representation can be nothing but a representation of which the first representation is the interpretant. But an endless series of representations, each representing the one behind it, may be conceived to have an absolute object at its limit. The meaning of a representation can be nothing but a representation. In fact, it is nothing but the representation itself conceived as stripped of irrelevant clothing. But this clothing never can be completely stripped off; it is only changed for something more diaphanous. So there is an infinite regression here. Finally, the interpretant is nothing but another representation to which the torch of truth is handed along; and as representation, it has its interpretant again. Lo, another infinite series." (PEIRCE CP 1–339)

So a sign process needs a representamen, an object and an interpretant to communicate something about the object to somebody in some aspect. There is no final and true object and representation. But as a KANTIAN 'thing in itself' PEIRCE operates with a 'dynamical object' that is the ideal limit of all the 'immediate object' that is created through interpretants and interpretant's interpretants.

The meaning of a sign (a representamen) is amongst other things set by its context, what the late WITTGENSTEIN (1958) in his language philosophy called the 'lifeform'. This is a concept that fits very well into biological motivational contexts. The red belly of a female stickleback for instance is the representamen for a male autopoietic system languaging with the female—because it is in a sexual mood—creating in him the interpretant that she is worth mating. Mating or reproduction is the context for the play of signs which in this specific mood—and only in this mood—of mating attains its shared meanings. PEIRCE uses the concept 'ground' for the context of interpretation in this central definition of the sign and its function:

"A sign, or representamen, is something which stands to somebody for something in some respect or capacity. It addresses somebody, that is, creates in the mind of that person an equivalent sign or perhaps a more developed sign. That sign which it creates I call the interpretant of the first sign. The sign stands for something, its object. It stands for that object, not in all respects, but in reference to a sort of idea, which I have sometimes called the ground of the representamen." (PEIRCE 1897, C.P. 2–228, Division of signs)

The sign becomes the immediate object that contains some aspect of the dynamical object. The immediate object is what the sign 'picks up' from the dynamical object and mediate to the interpretant based on the ground, the motivation or the life form. So the sign becomes a kind of mediator that is included in the interpretant because it is only recognized as such through the making of an interpretant. The interpretant is created through a specific ground which determines the aspect of the dynamical object that is of immediate interest in the given situation. The suggestive value is always working in the context of a life form both in biology and in human cultural life. The key to the understanding of understanding and communication is that both the animals and we humans live in self-organized Umwelt, which we do not only project around us but also project deep inside our system. The organization of signs and the meaning they get through the habits of the mind and body follow very much the principles of second order cybernetics in that they produce their own eigenvalues of sign and meaning and thereby their own Umwelt and internal mental organization in the autopoietic system.

As I see it this view of interpretation and meaning is well in accordance with WITTGENSTEIN(1958) who in his language philosophy says that the meaning of words/signs can only be defined in a language game, such as seduction or writing a scientific paper for instance, which again only arises as part of a life form, such as mating or scientific research. For developing the semantic aspect of the ethological concept of sign stimuli I prefer to use the WITTGENSTEIN inspired concept of *sign game* (BRIER 1995)—to explain how context and motivation work together—as a way to state the biological foundation of language without claiming that animals have language. I am stretching WITTGENSTEIN's life form concept into the animal kingdom. I am taking him seriously on his idea that life forms and language games are part of our natural history. The concept of sign game connects at the same time to PEIRCE's second order theory of signs.

Second order cybernetics says that it is only through the established structural couplings that signs can acquire meaning. What second order cybernetics gives to bio-semiotics is the ideas of closedness, structural couplings and languaging.

We thus combine second order cybernetics and PEIRCE's triadic second order semiotics to what I call *cybersemiotics* (BRIER 1995, 1996a, b, c) It is my opinion that this cybersemiotic frame of thinking take us a step forward in the understanding of how signs get their meaning and produce information inside communicative systems. *Information is actualized meaning in shared sign or language games.*

Conclusion: Peirce's semiotics as a possible bridge

In PEIRCE's semiotics everything in nature is a potential sign. Here is a meeting point with BATESON from cybernetics where information is a difference that makes a difference. Every difference is potential information and becomes informative through the self-organizing cybernetic mind function in BATESON's theory. But actually this only happens through the creation of meaningful signs. *With PEIRCE we can say that differences become information when an interpreter—an autopoietic system—sees them as signs.*

In humans these signs are organized into language through social self-conscious communication and accordingly our universe is organized also as and through texts. But that is of course not an explanation of meaning. It is an attempt to describe the dynamics of meaning generating and sharing systems and how they are organized. What living systems make can be called umwelten or better *signification spheres*. They live in

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a sphere of signification of their own making through the intercorrelation of Firstness (Representamen), Secondness (Object) and Thirdness (Interpretant) to semiosis consequently creating an informational world or reality. PEIRCE's reflexive or cybernetic definition of the interpretant points into culture, history and the never ending search for truth and knowledge. It underlines habits and historical drift, as MATURANA and VARELA do, to be the social constructor of meaning.

Now animals do not have language with syntax and generative grammars, so I suggest to call what they do for *sign games* (BRIER 1995). So the structural coupling of mating creates the sign game of the mating life form. I think that this is a fruitful specification in biology of PEIRCE's idea that the meaning of signs is created in the semiotic web of society. To make PEIRCE and WITTGENSTEIN meet we further stress that the unlimited semiosis means, that the interpretants of signs are created both through biological evolution and through cultural history as also LAKOFF (1987) stresses. The biological, mental or social habits of PEIRCE that are the meaning of the signs are equivalent of the language games insertion into the life forms of WITTGENSTEIN. WITTGENSTEIN did not care much about biology. But seen from both ethology, second order cybernetics and biosemiotics the basis for the human life forms and language games is the creation of sign games in our natural history, where the habits are called instincts. The instincts can in different degrees be combined with individual learning to make the communicative act possible, such as in bird song.

Through this combination we have now one big evolutionary narrative going into the human history of languaging and we have left the mechanical–atomistic—and deterministic—ontology and its epistemology of the possibility of total knowledge (world formula thinking). Evolutionary science is science within time attempting to find relatively stable patterns and dynamical modes (habits). It is not a science of eternal laws. It is a science of the habits of evolution and the meaning they come to have for the living systems created in the process. PEIRCE does not have an atomistic world view and his idea of firstness is both continuous, truly complex and chaotic and it posses potentially the primary aspect of both the 'inner' and 'outer' world. Consequently, it has much in common with the modern idea of the 'quantum field' except that PEIRCE does not let firstness be devoid of potential qualia and emotions. His world view is thus fundamentally anti-reductionistic and anti-mechanistic and evolutionary. I have written more about this in BRIER (1992, 1993a and b, 1996a and b).

The implication of this is that qualia and 'the inner life' is potentially there already from the beginning, but they need a nervous system to get to a full manifestation. The point is that organism and their nervous systems do not create mind and qualia. The qualia of mind develops through interaction with the nervous systems that the living bodies develop into still more self-organized manifested forms. PEIRCE's point is that this manifestation happens through the development of the triadic semiosis. We become conscious beings through the semiotic development of the living systems and their 'signification spheres' into communication through the ground of sign games and finally in humans language games. This is the new foundation I suggest ethology and evolutionary epistemology is interpreted and developed further from.

Notes

1 In the words of dynamic and gestalt oriented psychologist Kurt Levin who was also involved in the creation of cybernetics through the first Macy conference.

2 REVENTLOW (1972) in his paper entitled 'Symbols and Sign Stimuli' points out the close relation between the ethological concept of 'sign stimuli' and the psychoanalytic concept of 'symbols'. In both situation the organism sees and reacts on stimuli in the environment, that is not 'the real thing', urged by a strong motivation. Both imagine that the build up of psychic energy lower the threshold of stimulation that can release the biological behavior, such as sex or aggression, to the extend that we would consider nearly hallucinatory.

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Zusammenfassungen der Artikel in deutscher Sprache

M. R. A. Chance
Towards the Derivation of a Scientific Basis for Ethics

Ausgehend von ethologischen Befunden wird der Versuch einer Begründung ethischer Prinzipien unternommen.

Ethologische Studien des Sozialverhaltens von „Altweltaffen“ (Cercopithecoidea) zeigen zwei unterschiedliche Formen des Sozialverhaltens. Der „agonic mode“ ist dabei vor allem durch strikte Rangordnung charakterisiert. Die Individuen sind vielfach bemüht voneinander Abstand zu halten. Der Aufmerksamkeitsfokus ist vor allem auf die Ranghöheren gerichtet. Dominanz- und Submissionsverhalten wird häufig gezeigt. Der Großteil der Gruppenmitglieder zeigt permanent einen rel. hohen Grad an Aktivität und Anspannung. Andere Formen des Sozialverhaltens zeigen sich bei den Hominoidea (mit Ausnahme der Gibbons), deren Sozialverhalten als „hedonic mode“ bezeichnet wird. Die Interaktionen zwischen den Individuen sind vielfältiger und nicht nur durch hierarchische Muster festgelegt. Der Aufmerksamkeitsfokus liegt nicht nur im sozialen Bereich, sondern auch den Umgebungseigenschaften wird ein beträchtliches Maß an Interesse und Neugier entgegengebracht. Körperkontakt zwischen den Individuen (grooming) wird häufig vollzogen.

Im Humanbereich zeigen sich Persönlichkeitsformen und auch Gesellschaftsstrukturen, die dem „agonic mode“ bzw. dem „hedonic mode“ nahestehen. Erstere sind durch autoritär–diktatorische Eigenschaften geprägt, während der „hedonic mode“ entspanntere und kooperativere Formen des Sozialverhaltens bedingt.

Werner Callebaut & Karola Stotz
Lean Evolutionary Epistemology

Verglichen mit den umfassenden programmatischen Ideen der Begründer der EE erscheint deren derzeitiger intellektuelle Einfluß eher begrenzt. Interessanterweise rücken einige neue und alternative Forschungsprogramme, die sich ebenso mit den Beziehungen zwischen Evolution und Kognition befassen zunehmend in den Vordergrund: Evolutionäre Psychologie, GIGERENZERS adaptives „behavior and cognition program“, HOOKERS “regulatory systems theory“, HENDRIKS-JANSENS „situated activity and interactive emergence“, Memetik – um nur einige wenige zu nennen.

In diesem Artikel unterziehen wir sowohl die EE im engeren Sinne, als auch einige dieser neuen Ansätze einer kritischen Prüfung. Wir empfehlen dabei eine Rückbesinnung auf die naturalistischen Wurzeln der EE, in Verbindung mit der Forderung nach einer wissenschaftlichen, das heißt anti-transzendenten und anti-transzendentalen Erkenntnistheorie für limitierte Lebenwesen – in der Hoffnung damit eine zukunftsfähige Version der EE zu inspirieren.

Alexander Riegler
“The End of Science”: Can We Overcome Cognitive Limitations?

„Weshalb können wir das Universum verstehen?“ fragt sich DAVIES (1990). In diesem Artikel argumentiere ich, daß Wissenschaft nicht ein Angelegenheit des Verstehens irgendeines Universums ist. Vielmehr ist sie, wie ihre Geschichte zeigt, eine überlegene Methode der Organisation von Erfahrungen, die zum Erstellen von Vorhersagen dient. Historisch gesehen begründen zwei Arten von Modellen die Wirksamkeit der Wissenschaft: narrative und mathematische Modelle.

Die jüngste „End of Science“–Affäre von John HORGAN erinnert uns an die ernsthafte Möglichkeit, daß der Fortschritt in der menschlichen Wissenschaft verlangsamt und schließlich an kognitive Grenzen stößt. Im Gegensatz zur romantischen Ansicht HORGANS, dem gemäß Wissenschaft nach *der* Wahrheit suchen muß, ist der Gegenstand der Wissenschaft nicht die „Realität“. Eher besteht sie aus hochentwickelten „Denkgerüsten", die Vorhersagen und die Entstehung von Bedeutungen ermöglichen.

Ausgehend von kognitiv–psychologischen Untersuchungen hebe ich hervor, daß aufgrund der menschlichen Natur der wissenschaftlichen Argumentation in beiden Modellvariationen Grenzen gesetzt sind. Mit dem Aufkommen von Computern können nun aber wissenschaftliche Untersuchungen auf „externalisierte Denkvorgänge" ausgedehnt werden, die unabhängig vom begrenzten menschlichen Kurzzeitgedächtnis und seiner Langsamkeit sind. Um diese dritte Variante, computationale Modelle, einsetzen zu können, müssen wir die prinzipielle Verwandtschaft der drei Modellarten anerkennen. Letztlich mag dies zwar nicht das (unbeantwortbare) Problem des naiven Realisten nach dem ontologischen Verhältnis von Modell und „Realität" lösen, es garantiert aber den Fortbestand zeitgenössischer Wissenschaft jenseits der menschlichen kognitiven Grenzen.

Nancy E. Aiken

Human Cardiovascular Response to the Eye Spot Threat Stimulus

In dieser experimentellen Studie wurde die Reaktion des Menschen auf den Augenstimulus getestet. Die Grundannahme war, daß aufgrund der im Tierreich weit verbreiteten Reaktion auf diese Reizgrößen auch beim Menschen eine unkonditionierte Reaktion auffindbar ist. Gemessen wurde dabei Herzfrequenz, Blutdruck und Durchblutungsgrad der Finger.

Die Reaktionsmuster die auf die neutralen Kontrollreize und die Augenreize gemessen wurde zeigten signifikante Unterschiede. Die Reaktionen erfolgten dabei in gleichem Ausmaß – unabhängig vom Geschlecht und kultureller Zugehörigkeit.

Von besonderem Interessen dabei – und darin besteht auch der größere Kontext dieser Untersuchung – ist die Wirkung derartiger Reize auf die Wahrnehmung von Kunst und die damit einhergehenden Emotionen.

Theresa S. S. Schilhab

Why Did Subjective Experiences Develop?

DARWINS Überlegungen zur Selektion als treibender Kraft evolutiver Prozesse kann auch einen Beitrag zur Arbeitsweise und Funktion des menschlichen Bewußtseins leisten. Der Philosoph Daniel DENETT geht in seine bekannte Büchern „Consciousness explained" (1991) und „Darwins dangerous ideas" (1995) davon aus, daß sich Bewußtsein im Dienste der Überlebensfunktionen entwickelt hat. Dabei besteht jedoch eine der wesentlichen Eigenschaften des Bewußtseins darin, bestimmte eigenständig erscheinende Empfindungsdimensionen zu beinhalten. DENETT unterscheidet in diesem Zusammenhang strikte zwischen „sensitivity" (Sensibilität) und „sentience" (Empfindsamkeit), wobei letztere vor allem mit bewußten Empfindungsdimensionen, bzw. subjektiven Bewußtseinsqualitäten („Qualia") verbunden ist. „Sensitivity" würde sich als die elementarere Eigenschaft erweisen, die vielfach mit rein physiologisch ablaufenden Prozessen verbunden ist.

DENETT geht davon aus, daß sich die sog. „Qualia" im Verlauf der Phylogenese im Dienste einer exakteren Klassifikation von diversen Umwelteigenschaften entwickelten, ohne anfänglich subjektive Empfindiungsdimensionen zu beinhalten. Diese traten bei Menschen auf – u.a. bedingt durch die Sprache, die höhere Formen von Intentionalität bedingt.

Jedoch erfährt bei DENNET die Frage, nach den spezifischen Qualitäten von Empfindungen („Warum tun Schmerzen so weh?") keine befriedigende Antwort.

Johannes Gadner

Embodying Culture

Es wird der Versuch unternommen aufzuzeigen, in welcher Art und Weise kulturelle Einflußgrößen an der Konstitution und Genese von kognitiven Strukturen mitwirken. Dabei interagiert eine biologisch vorgegebene Basis mit jeweils spezifischen soziokulturellen Faktoren. Leitidee ist dabei die der „Verkörperung" (Embodyment), welche für die kognitive Anthropologie, wie auch für andere Bereiche der Kognitionswissenschaften von großer Bedeutung ist.

Der Term Verkörperung wird dabei auf unterschiedlichen Ebenen – beginnend mit der sensomotorischen Ebene analysiert. Es zeigt sich, daß – gemäß der PIAGET'schen These – die Handlung (Aktion) besonderen Stellenwert einnimmt. Dabei findet im Verlauf der Ontogenese eine Verkörperung der Aktion hin zur Kognition statt, wobei dieser Prozeß jeweils in einem soziokulturellen Rahmen eingebettet ist, worin die enge Verschränkung von biologischen und soziokulturellen Faktoren deutlich wird. Weiterführend zeigt sich im Prozeß der Enkulturation eine weitere Facette der Verkörperung indem hier u.a. mithilfe der Sprache diverse Normen und Werte im „kognitiven System" entstehen.

Im Konzept der Verkörperung wird auch wiederum die Notwendigkeit interdisziplinärer Zugehensweisen und der damit verbundenen Integration natur- und sozialwissenschaftlicher Ansätze deutlich.

Paul C. Kainen

Mathematical Cognition

Hier wird die These aufgestellt, daß jegliche Kognition mathematisch organisiert ist, was durch ein metamathematisches Modell begründet wird. Dabei wird ein kognitives System aus folgenden Bestandteilen bestehend aufgefaßt: Objekte (Fakten), Interaktionen und ein Kalkül welches Fakten und Interaktionen interpretiert. Im Bereich der Biologie wäre ein Beispiel für derartige „Fakten" neuronale Aktivität, Zellteilung, Populationsfluktuationen… Die Interaktionen erweisen sich als strukturierte Prozesse – wie z.B. ein Räuber–Beute–Verhältnis. Zentrales Merkmal der „Fakten" ist ihre „Selbstbezüglichkeit", die in einer annähernden zyklischen Form zum Ausdruck kommt. Diese „Fakten" sind mathematisierbare Objekte, die untereinander in verschiedene Formen der Interaktion treten können. Dabei treten spezifische Algorithmen auf, die zu einer Schließung der Zyklen führen können. Interaktionen zwischen diesen Zyklen können unterschiedlich interpretiert werden, wobei vor allem die algebraische Form der Interaktion ein Modell für Kognition abgibt.

Søren Brier

The Cybersemiotic Explanation of the Emergence of Cognition

Die LORENZ'sche und TINBERGEN'sche Ethologie stellt einen Mittelweg zwischen reduktionistisch–mechanistischen Ansätzen einerseits und vitalistischen Ansätzen andererseits dar. Darauf aufbauend entwickelte der Dänische Ethologe REVENTLOW ein Ethologie und Psychologie vereinigendes Konzept, welches den Kognitionswissenschaften eine bio–psychologische Basis vermitteln soll. Eine fruchtbare Erweiterung dieses Ansatzes wiederum findet sich in den Arbeiten BATESONS, VON FOERSTERS, MATURANAS und VARELAS mit den wegweisenden Konzepten von selbstorganisatorischen kognitiven Prozessen, Autopoiese und „second order cybernetics"

Jedoch bleiben all diese Ansätze eine Begründung hinsichtlich der Entstehung von Bedeutung im Bereich kommunikativer Prozesse schuldig. Genau hier erweist sich die Semiotik von J. S PEIRCE als Brücke zwischen reduktionistischem Materialismus einerseits und radikalem Konstruktivismus andererseits. Indem „second order cybernetics", die Information als intern erzeugtes Element eines autopoietischen Systems erachtet und PEIRCE's triadisches Modell (Zeichenträger – Designat – Interpretant) zur „cyber semiotic" zusammengefaßt werden, wird das Verständnis über die Entstehung von Bedeutung innerhalb kommunikativer Systeme einen beträchtlichen Schritt vorwärts gebracht.