12. Comparisons Between Human Perception and Machine "Perception"

12.1 Introductory Remarks

In this second part of the book we shall investigate how one can establish relations between the concept and the performance of a synergetic computer and our understanding of cognitive processes in the human brain. Or, to be more modest, we shall ask the question: To what extent can the synergetic computer mimic mental abilities?

We first discuss the aspects for which this comparison will be made, what its limitations are, and what its prospects may be. First of all there are some general indications that the brain behaves as a synergetic system. It is an *open system* that consumes energy. By means of PET (positron emission tomography) one may even make visible the areas in the brain where enhanced energy consumption takes place when specific tasks, e.g. speaking, are performed. As neuroanatomy and neurophysiology tell us, the brain is composed of a large number ($\approx 10^{10} - 10^{11}$) of interacting parts (the neurones). It is self-organizing – for instance our thoughts can be produced without external inputs. Rather unspecific control parameters may change the macroscopic state of the brain. These control parameters may be drugs supplied from the outside, or internal neurotransmitters such as serotonin or dopamin. Within certain limits, their action can in turn be controlled from the outside, for instance by blocking dopamin$_2$-receptors by haloperidol. Even the staunchest behavioralist, who ignores internal states of the brain, will have to admit that upon taking certain drugs a person will change his or her behavioral pattern. In perception we observe a further phenomenon known from synergetics, namely symmetry breaking (vase-face), or more precisely, oscillations (Chap. 13). Critical fluctuations and critical slowing down – two typical effects known from nonequilibrium phase transitions in synergetics – were found in the motor system (Haken et al.; Kelso, Schöner).

In the following we shall attempt to put the idea that the brain is a synergetic system on a still stronger footing. We shall compare the performance of a synergetic computer with that of a brain under specific conditions. In doing so we shall use known experimental facts, and make predictions that can be checked experimentally. Thus our approach is fully operational. We must be aware of at least two problems in this study, however:

1) Our brain undoubtedly is a complex system, and probably the most complex system we know of. Complex systems can be viewed under many aspects, and their behavior is practically inexhaustible. We shall thus be able to study only a limited number of specific features of the brain's performance, maintaining the

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hope, however, that in the course of time more and more features can be subsumed under a general concept (conceivably that of synergetics!)

2) In synergetics it has been shown that even the most diverse systems may behave in an analogous fashion. This implies that the same phenomena can be realized in quite different material systems. Synergetics is thus a theory of structural relationships and not a theory of matter per se. This may provide some philosophical basis for our attempt to compare the performance of a brain with a synergetic computer.

On the other hand, from a knowledge of the macroscopic phenomena alone we cannot draw unique conclusions about the structure of a system (e.g. a network) at the microscopic level. A typical and explicit example is provided by the quite different network-realizations of a synergetic computer that were discussed in Chap. 7.

Summarizing, we may state that synergetics can establish profound analogies between different systems at the macroscopic level and it may also give hints as to where to look on the microscopic level; but it definitely cannot replace the detailed experimental work at the macroscopic and microscopic levels. Thus the excitement aroused by experimental work is quite justified and will continue to play an important part in advancing our knowledge. After these general remarks, let us make some attempts at the announced comparison between brain and computer.

Let us begin by discussing whether one might experimentally check the paradigm of synergetic computers as a model of cognitive brain functions. As we have seen in Chaps. 4 and 5, the systems may acquire specific attractor states $\boldsymbol{q}$. If one attractor is occupied, the system cannot simultaneously occupy another one. There are strong suggestions from speech research, which support this approach.

One of the simplest tasks in language is naming objects. Let us review some studies of the path connecting thought to the spoken word. Levelt and coworkers found that there are two well-defined steps on this path. When we wish to name something, first a so-called lemma is activated, i.e. a mental representation of the meaning of the word. Only then, in a second step, is a sound produced. Sometimes we arrive at the lemma but not at the sound of the word.

The experiments are performed as follows. The scientist shows the test person a picture, for instance a sheep, on a screen. The test person has to name the object. Usually after 0.6 seconds the test person says "sheep". During this latency time, first the lemma and then the form of the sound ("Gestalt" of the sound) must be produced in the brain. To study whether meaning and form of sound of the word are present simultaneously, the following experiments were done.

Shortly after the picture of a sheep had been shown, but before the subject could pronounce the word sheep, words of similar meaning *or* similar sound are offered to him or her by a loudspeaker. The results are: In the first half of the latency period words with similar meaning (such as cow or goat) but not those with similar sound are recognized *with delay*. In the second half of that period, the words with similar sound are suppressed.

These findings can be quite simply explained if we assume that lemmas and formation of sound are represented by two kinds of state vectors each belonging