A META-THEORETICAL SYSTEM FOR CONSTRUCTING CORRESPONDENCES IN COGNITIVE SCIENCE

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Abstract

A fundamental issue in cognitive science is the question how to accomplish a multi-disciplinary cooperation between the disciplines involved. The problem is that we lack a meta-theoretical framework, or guidelines about how to sort and match different perspectives. I propose to dismiss the standard approach that reduced different views to the single unifying concept of "information", and to move towards a meta-theoretical perspective striving to point out correspondences between various accounts. To describe such correspondences, I suggest some general concepts: state, event, flow, flow-chain. A single common sense fact may be variously described by different disciplines as the state of a brain area, or of the body, or of consciousness, and so on. As states follow one another in time, different events, and flows (sequences of events), may also be described by using the languages of diverse disciplines. To examine correspondences, we can consider different flows in parallel at the same time interval (a flow-chain), including several flows (physical, behavioural, sensorial, of consciousness, etc), and establish horizontal (between events in the same flow) and vertical (between events in different flows) links. Such links may have causal or correlational nature. Examples of analyses of specific tasks are provided and some consequences for communication between disciplines are discussed.

1. Introduction: Cognitive Science as a Unitary Discipline

Cognitive science meetings are regularly held nowadays; the most commonly recognised aim of such meetings is that of contributing to confrontation and cooperation between different disciplines interested in cognition. How such confrontations occur and proceed, and how cooperation may be realised is not clear. I argue that the problem is that we lack a meta-theoretical framework or guidelines about how to sort and match different perspectives. In this paper I provide a sketch of a meta-theoretical system of this kind.

Generally speaking, the main reason for adopting a multidisciplinary approach in science is to get a better explanation of some phenomena. Common sense already has explanations for everything, including what we call cognitive phenomena.

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Science comes into play when we want to have strong reasons to agree about a particular explanation. A good explanation should be one that gives us good reasons-why, even though not necessarily causes of phenomena. Life is a complex phenomenon and simple explanations are never enough, because there is never a single perspective that explains everything. Explanation depends on our purpose and on the context in which we are placed; all different explanations may be true in a sense, but some are more appropriate, more informative in a particular context.

Phenomena that cognitive science wishes to explain better by "joining forces" of different disciplines have to do with a single object: cognition. Is this a clear object? If we judge from what different cognitive disciplines actually study, we can get confused because we are not even certain that they study cognition in the etymological sense (everything that has to do with knowledge or knowing): perhaps we can call it 'science of mind' or 'noetic science' (O'Nuallain, 1995). The question "what is mind" is even more difficult than the question what cognition is.

In fact, every single discipline defines clearly what it is about - as a scientific discipline, not common-sense talk - when criteria are defined that tell us what evidence is acceptable inside the discipline, which descriptions are acceptable. Each discipline has redefined and specialised the concept of cognition for use within its own domain. The various disciplines concerned with cognitive science do not seem to talk about the same things because they use very different languages: representations, cortical responses, connection weights, qualia, concepts, etc. So how to solve the problem of a multidisciplinary perspective?

A first solution is to argue that even if different disciplines apparently talk about different objects, they actually have a single, same object, namely they deal with information systems. This is a classical answer, in fact the first answer dating back to the early days of cognitivism, for example by Alan Newell (1990). Knowledge is organised information and cognitive systems are systems that manage and use such information. This perspective is what Clark (1989) called the "uniformity assumption". It implies that cognition may be explained by a unifying approach like the computational approach. This assumption is even stronger, because a computational description or explanation would be the best, and is to be preferred over the others (Dalenoort, 1995).

The idea of a unifying role for the computational perspective has several problems, however. The first is that such a unifying role is reductionistic in a sense, because it does not try a confrontation or integration with other approaches, but simply asks for a translation into the computational language. The second problem is that the computational approach is not so clear, because the concept of information in its original sense is based upon the concept of reduction of uncertainty, when one has to choose among a number of alternatives. But we know that the concept of uncertainty depends on the context of what one already knows, so knowledge is not explained but presupposed by information. Also, today, connectionism has changed the very idea of information processing, because processing is not just symbol manipulation anymore.

A second solution to the problem of a multidisciplinary perspective is the idea that cognition takes place at different levels, and that different disciplines should be distinguished according to the considered level of description. At the high level semantic, intentional, conscious aspects are relevant; this is the domain of psychology, philosophy, and symbolic old-fashioned artificial intelligence (AI). At the low level questions concern sensory processes, brain activity, hardware; this is the domain of the neurosciences and of connectionist networks. Cooperation then would be the process of describing how to go from the low-level to the high-level, and reverse. If we accept to exclude the uniformity assumption, then the levels distinction seems to make things clearer because one can think that some models are more adequate for high-level processes, other for low-level operation.

However, it is not obvious that disciplines are compatible even at the same level: for example, philosophy and psychology are at the high level, but philosophy may be speaking about intentionality, psychology about mental models; the neurosciences and connectionism are at the bottom level, but the former may be speaking about brain areas, whereas connectionism uses concepts like 'vectors in activation space', and so on. Hence the distinction between levels seems to be of little use from the point of view of multidisciplinary cooperation.

A different solution to the problem of a multidisciplinary perspective, the one we are proposing, is that different accounts are compatible if we consider them as talking about something more general than special aspects of cognition, namely about the unique "fact" present in the common sense perspective, which needs to be explained (e.g. a task). It is true that each cognitive discipline describes and explains the same common-sense fact from a specific point of view, using specialised predicates, but this should not lead us to consider such different accounts as excluding each other or as being incompatible. The further step is to establish correspondences between different accounts. This means going beyond a simple catalogue of different descriptions of facts. Instead it involves the construction of a meta-theoretical map for the translation of one description into the other in the context of specific empirical data (particular tasks) (Note 1). This does not imply that different descriptions should lead us to a unifying model such as an information model, but that they simply give answers to different questions about a single object, or about a single cognitive phenomenon, that belongs to a cognitive task.

2. Definitions

The most immediate approach for comparing approaches is not to speak in abstract terms, like we usually do, but to analyse a single task. In a cognitive task a cognitive system uses or manages knowledge. It may be described from different standpoints in various ways: as a kind of response, a response time, activated cortical areas, information-processing, activation patterns, connection weights, and so on. Such different descriptions express a number of points of view: behavioural (what happens is described as a response, variable in kind, reaction time, etc.), brain activity (activation of particular brain areas in well-defined moments in task), computational (information-processing steps, or algorithms; a description that could be implemented in a symbolic simulation model), neural networks (particular activation patterns, or connection weights), phenomenal (a particular experience or idea), etc.

The most general dimension that allows considering phenomena in parallel is time. Considering things in time was the main merit of the concept of process, ubiquitous in cognitivism. The basic element in the system I am proposing is a snapshot of a common-sense fact in a single time, something that we can call a 'state' (Note 2). In time perspective, a system may assume different states in sequence. This is what actually happens in a process. Processes can be considered, in such general terms, as changes of state of a system in time. In such a way it is possible to recover the time dimension without being restricted inside the boundaries of the computational metaphor.

States follow one another. More precisely, we can identify another state just when the former state changes. We call "event" this change of state, and "flow" a sequence of events in time. We shall call state changes in a cognitive system cognitive events. When we consider different flows in parallel at the same time interval, we have a flow-chain.

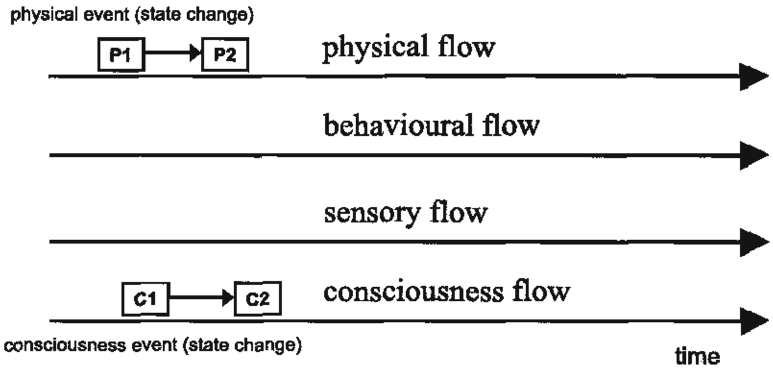

Figure 1, A flow chain.

3. Flows in a Chain

Let us consider a chain of flows from several perspectives. At every single moment in time many things happen simultaneously. The physical flow includes events like electromagnetic changes (e.g. light), sound waves, changes in the chemical composition of air, etc. We can distinguish as many physical flows as the number of physical dimensions that we can consider. A variety of physical events happen in our own body (e.g. if someone cuts one finger, or the body gets in contact with an electric current).

Our physical environment continuously changes and, if we are not in a state of sensory deprivation, external and internal physical states change in our body. The neural and sensory flows include a special category of physical events that happen in our senses or in our nervous system. The behavioural flow includes the system outputs, considered at a molecular (single muscle contractions or glandular secretions) or molar level (speech, actions, etc.). There is also a flow of consciousness (a revival of a concept that dates back to William James); this is the only flow that includes non-observable events, that refer to introspective reports (perceptions, feelings, beliefs, representations, etc.)(Note 3).

The description of such flows has been made only to exemplify. Different or finer distinctions could be made: generally speaking, each cognitive discipline could define its own flow (e.g. a linguistic flow could be cut out inside the behavioural flow). The main idea is that all such flows should be considered in parallel, to highlight the correspondences and possible causal connections.

4. A Sketch of a Multidisciplinary Cognitive Model

In this section I shall describe how a multidisciplinary (meta-theoretical) model can be constructed and how it works. In the domain of mental and behavioural events, it is necessary to clearly distinguish between two kinds of descriptions and explanations: the description made by the same subject or system interested in the event, and the one made by a different subject or system that takes the event as object. We generically speak of a flow-reader to indicate the system that reads flows.

To read flows means to identify states and events in a system, for example a physical state or a conscious state, by using the relevant vocabularies (in the former case of physics and in the latter of psychology). Since one of the objectives is identification, a flow-reader operates like a categorial system. As stated before, states follow one another, and when there is sequence there is change of state (an event). A description of an event, then, includes the description of an initial state, a transformation or change, a subsequent state. As examples of events, we can consider a stimulus appearing, that formerly was not present (a physical variation happens); or an idea that appears or transforms itself into another (Note 4). In a continuous flow a different "quantisation" of discrete events is possible. The flow-reader operation may have to be sensitive to differences (in terms of categorisation theory: to make relative discriminations), or to be able to identify the nature of differences (to make absolute discriminations). As various cognitive disciplines categorise flows in packets or quanta by using predicates which are not translatable one into another, we have a collection of events that refer to the same common-sense phenomenon but that are described in different languages, using different protocol criteria. Such descriptions can also be hypothetical statements and true theories or explanations of the phenomenon, but always different and not related to each other.

The aim of a multidisciplinary cognitive science, of getting a synergy from separate descriptions and explanations, can be accomplished if links between different flows can be set up, and correspondences constructed. Links between events may be causal or correlational. Two kinds of links are possible: horizontal, concerning relationships between events along the same flow, or vertical, concerning relations between events placed at the same point in different flows. Correspondences can be constructed, then, by isolating parallel events in time in different flows. It should be noticed once again that they actually are not different events but only different descriptions of a single phenomenon. Links shown in Figure 2 are only fictitious examples of causal (solid arrows) and correlational (dotted arrows), horizontal and vertical, relations. (An early sketch of this idea, relating to the idea of "mental causation", was clearly outlined in Dalenoort, 1990).

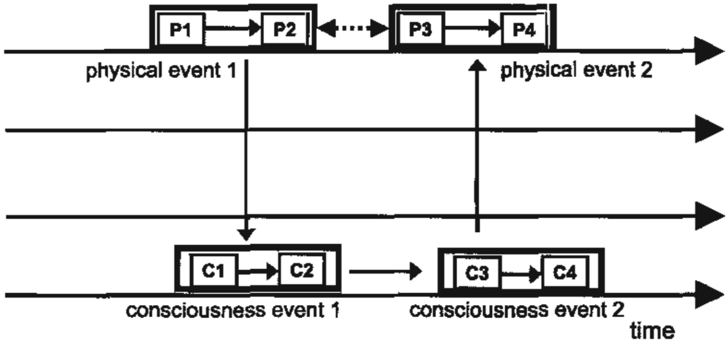

Figure 2, Examples of links in a flow chain.

The specific language of one discipline may be more or less suitable to identify and describe as single events certain packets of variations in a flow. Sometimes it is also possible to describe what relations connect some event to the next (usually a causal link). In other cases one explanation is not possible with respect to the same flow, where only correlational links may be posed, and for a better account a different flow must be considered; this is tantamount to using a different discipline, with a different language, and this is why a multidisciplinary perspective is necessary. In the example illustrated in Figure 2, the second physical event may be better explained by referring to a series of conscious events.

5. Some Specific Examples of Multidisciplinary Models

In this section we shall consider some concrete examples. The first is reinforcement in classical conditioning (Figure 3). If events are read horizontally, changes are categorised in a given flow: in the physical flow, the event description is the description of a stimulus and of its conditions (e.g. meat must be visible); in the behavioural flow, it is the objective description of behaviour (e.g. an act of eating); in the sensory flow, processes that make the sensory systems receptive to the stimulus are described; in the consciousness flow there is the description of a subjective experience (e.g. perception of meat, its being classified as a "reinforcer", need satisfaction, etc.).

The vertical reading of flow representation highlights how some links may be of a correlational type if one stays inside a particular flow (horizontally), and a causal explanation may be found when moving vertically to other flows. The process of meat that appears and that is being eaten cannot be explained only in physical terms (at the level of physical events); the perception of the meat and its being considered for eating as a reinforcer, must be mediated by cognitive events, etc.

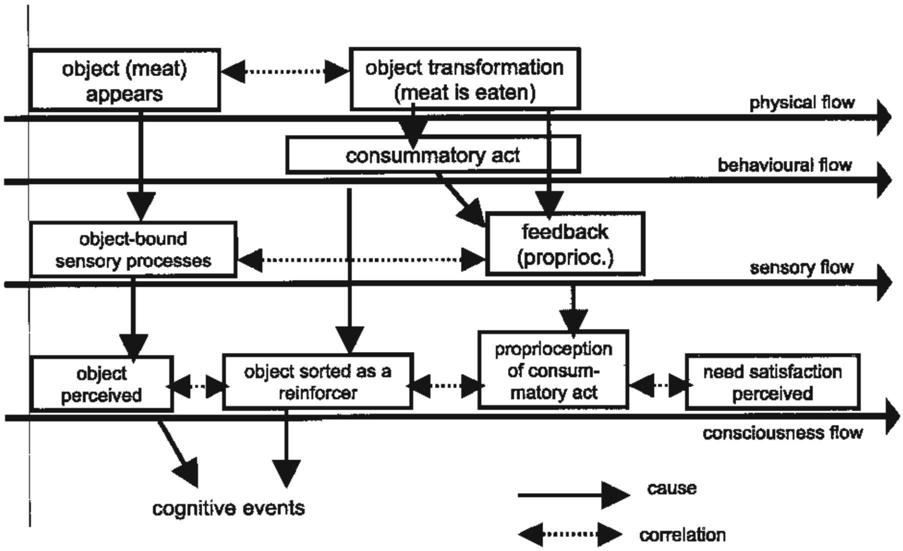

Figure 3, A "reinforcement" phenomenon.

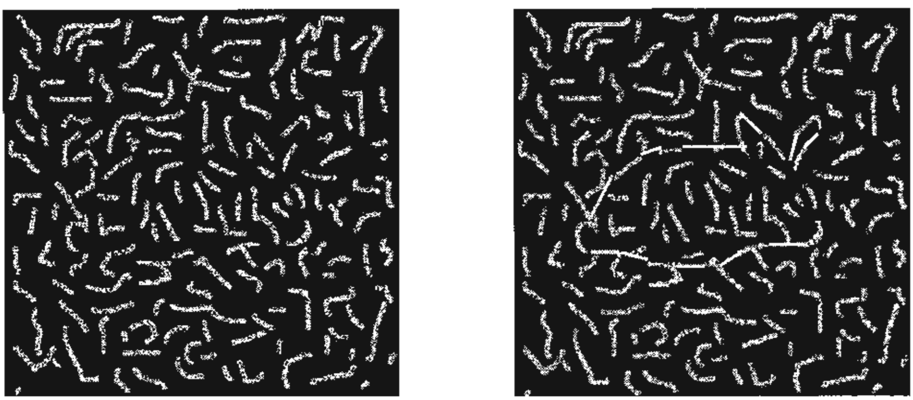

Figure 4, A fragmented picture with a hidden shape.

We consider a more complex example. We shall analyse an experiment (Eriksson *et al*, 2004) where brain images are used to test the hypothesis that the beginning of perceptual awareness and its maintenance in time (called sustained perception) are two different processes. This experiment is arranged as follows. First a fragmented picture is shown (Figure 4), apparently depicting some coarse sticks but containing a hidden animal shape. After some time, a subject may be able to identify the target, which seems to suddenly "pop up". As the subject has been instructed, when this happens s/he pushes a button and hears a beep. According to the instructions, the subject must continue to look at the picture until s/he hears a beep again, and when this happens (10 sec. after pop-up) s/he must push the button again. The picture stimulus does not disappear immediately, but lasts in any case 10 seconds more. The second button push, a second motor response, has the purpose of checking whether the brain activation concurrent with the first response was due to target identification (pop-out) or just to the response being given. The second time there is the same situation (pushing the button, same beep), but in this case perception is sustained. According to the authors, their results provide support for the hypothesis y that the initial creation of perceptual awareness and upholding perceptual awareness over time are separate processes involving different brain regions.

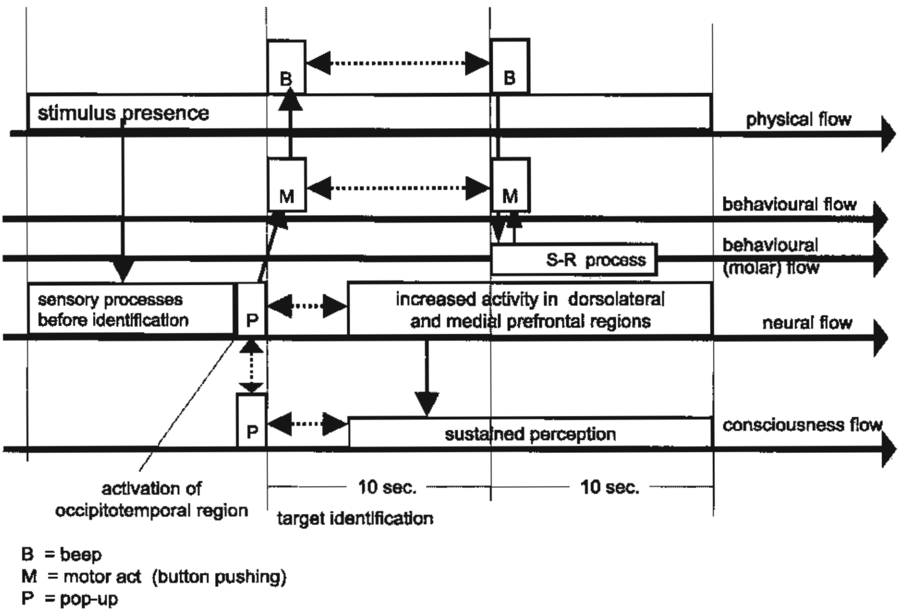

Figure 5, Perception of a fragmented picture.

Figure 5 shows a multi-dimensional diagram for this task. Since the actual purpose of the present description only is to illustrate the proposed system, only its formal aspects are evaluated. In other terms, the particular layout, or proposed links etc. are not discussed.

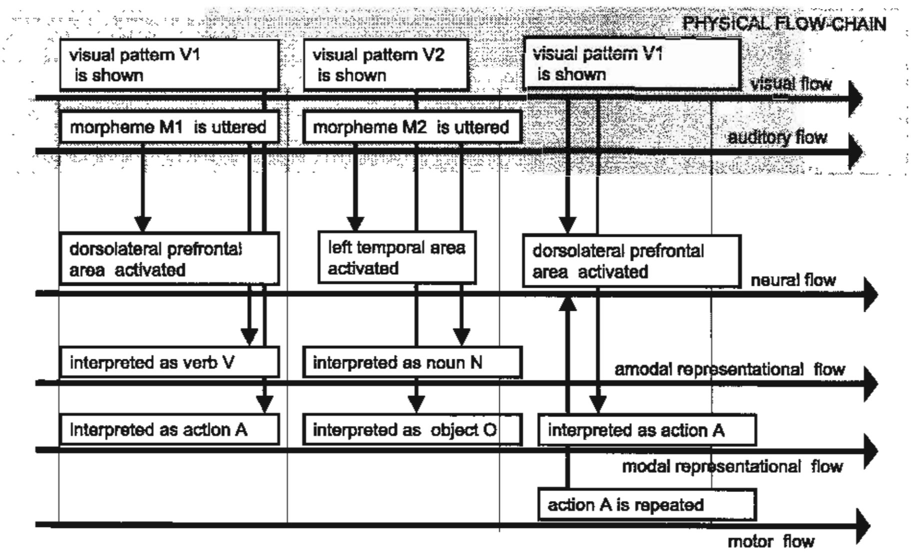

Figure 6, Amodal and modal representation of objects and actions.

A still more complex example is shown in Figure 6. This model illustrates the fact that the perception of verbs and nouns activate different areas in the brain (Pulvermueller, 2003; Cappa & Perani, 2003) and that the same areas are activated while the subject observes and performs the same action (Rizzolatti *et al.*, 1996). In the mimicked task a visual pattern and a morpheme are presented at the same time, and we see that when the visual pattern was interpreted as an action, and of course the morpheme was interpreted (in CS flow) as a verb, then a certain brain area was activated; next time, the visual pattern was interpreted as an object, the morpheme as a noun, and the brain area was different. In the right part (latest time), the subject sees a visual pattern, interprets it as an action, and performs the action himself. Here the model captures, according to empirical data, the simultaneity of the activity in the same brain areas, during observation and performance of the same action. It is worth noting that, of course, it normally happens that there are many concurrent different physical states (light, sound, touch, smell, etc.); as a consequence in this case the physical flow has been decomposed into a visual flow and an auditory flow, both being considered as flow-chain subsystems.

Finally, Figure 7 shows a complex multidisciplinary model of a fictitious task where subjects are presented a gesture and asked to name and repeat it. Here different flow-chain subsystems have been considered. In the upper part, the physical (visual and auditory) flow and the subject flow (with its motor, neural, and representational aspects), which obviously interact. In the lower part, a symbolic and a neural-network model of the same task have been considered; in these cases, of course, there is no vertical link; however, this could be the case if a hybrid symbolic-connectionist model had been devised. The purpose of the present exposition is, again, only to show the potential uses and applications of the proposed metatheoretic system, rather than to discuss particular models.

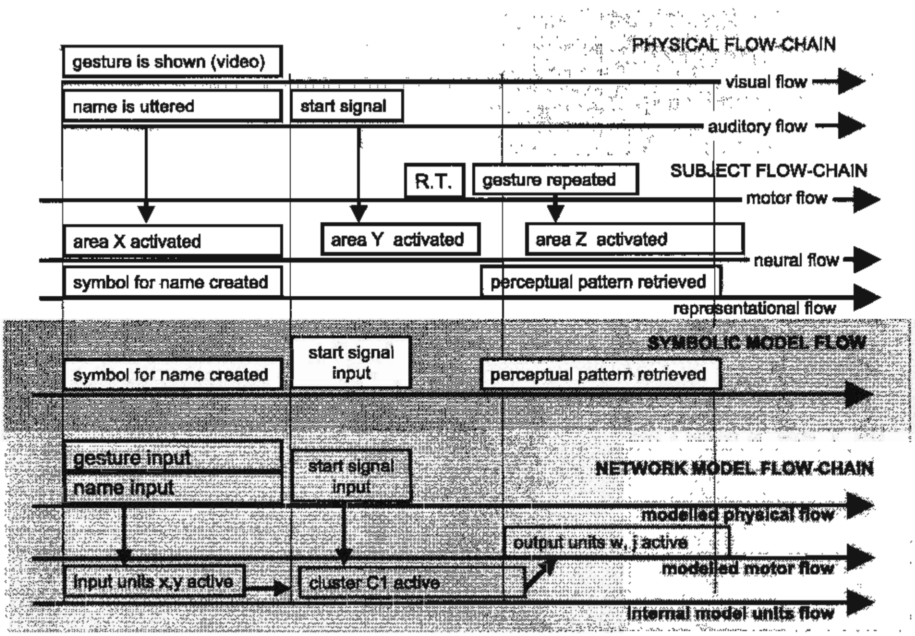

Figure 7, A complex multidisciplinary model

6. Conclusion

In this paper the outline of a meta-theoretical framework has been given, suitable to facilitate multidisciplinary cooperation, which is the substance of cognitive science. We have suggested that the computational metaphor, as a unifying assumption, and the simple distinction between levels should be overcome, towards a more general redefinition of the object of cognitive science as a science of cognitive tasks. The proposed idea is to replace the concept of "processes" with the one of parallel flows of events (state changes in a time dimension), i.e. a flow-chain, categorised by different disciplines as packets or quanta; correspondences are specified by their being linked to the same points of the flow-chain. We considered two kinds of links between events, horizontal and vertical, and each may have causal or correlational nature. The proposal has been exemplified by considering, in specific tasks, different flows pertaining to different perspectives, as the consciousness, sensorial, behavioural, and physical flows.

This method may help to recognize two different kinds of misunderstanding between disciplines, that have different origins. Descriptions may be different either because they refer to different events in the flow-chain, or because they refer to different links between events.

In some cases the problem arises from the identification of the object of discourse: this is a horizontal problem, of categorisation, and should be left to each single discipline with its particular language, toolset, accepted rules, and criteria.

As an example, take an account of "dyslexia". What dyslexia is (how it is defined), depends on what track we are following in our flow-chain. In the behavioural flow, it is a sequence of acts (events) manifested by a subject engaged in particular tasks (e.g. reading), showing typical problems. In the flow of the conscious processes, it is the concurrent sequence of introspective data that the subject is experiencing while recognising a word, etc.. In the neural flow, one possible representation of it is as a magnocellular deficit. It would be nonsense to quarrel about what the "right" description should be, and it would be a misunderstanding to try to directly compare among them different perspectives. The same holds, of course: for explanation, for example, some events concerning information-processing may be interpreted as causing wrong or inadequate outputs, or some neural deficits as causing inadequate sequences of states in the brain. Since they use different categories, different cognitive scientists are really speaking of different things; to understand the relevance of what a neuroscientist says about dyslexia, one has to be a neuroscientist, or to know enough about this domain of knowledge.

When the problem is not "what we are speaking about" (which is taken as given) but what the explanation is (what connects one event to another), it may be necessary to establish links between disciplines. In the dyslexia example, one may be tempted to say that a magnocellular deficit causes a wrong sort of information-processing, which causes a poor performance in reading. An account like this can lead also to a misunderstanding between different disciplines, because causal links are vague and too generic. To establish correspondences, an anchor point is required: the proposed solution is to adopt the time scale where different events can be identified and located in parallel. In our example, if links are established at different moments during the execution of a task, it may well be that in some links a neural deficit accounts for some behavioural aspects but, in other links, that former behavioural events, or former representations, or former procedures, etc., may have had also an effect on behaviour or even on the very neural later events.

Other advantages of the proposed solution concern the possibility of clearly declaring whether a first-person (subject's) or third-person (researcher's) perspective is adopted, and comparing them; or the possibility of considering in the same framework both the active and passive aspects of consciousness and of behaviour (e.g. to define events in consciousness is an active fact, but the corresponding processes may be considered in different flows, as implicit processes that are not active but generate "results" available in consciousness.

Notes

1. The concept of correspondence is inspired by the correspondence principle in physics (introduced by Bohr), that states the similarity of two physical laws belonging to two different theories (e.g. the Newtonian theory and the general theory of relativity, where the second for low velocities reduces to the first. Similarly, the laws of quantum mechanics applied to macroscopic systems reduce to the results of classic mechanics). According to our proposal, models of different disciplines do not exclude each other and may be compatible. Likewise, in physics, thermodynamics was not "reduced" to statistical mechanics.

2. According to previous claims, there may be different descriptions associated with a state. Neural language may refer to the state of a neuron, or of a brain area; behavioural language may refer to a glandular secretion, or to a muscle or body movement; phenomenal language may refer to a state of consciousness, and so on. For brevity, we shall elliptically speak of "states" instead of "descriptions of states". The word "description" is always implied also in the concepts defined further: so by "events" and "flows" we mean "descriptions of events" and "descriptions of flows".

3. From the comparison of the flows of consciousness and of behaviour some surprising similarities can be discovered: it is impossible "not to behave", as it is impossible "not to think"; behaviour, like consciousness, has an active (voluntary) aspect, and a passive aspect (both ideas and actions may "happen" independently from the subjective control). The concept of consciousness, in fact, has two aspects, contradictory but both essential. On one side it seems to "appear", on the other side it seems to "control "mind; this dilemma is related to a similar contradiction between its being both content and process (only contents automatically appear, but we are aware only about contents). William James' idea has captured the fact that at every moment in time we are aware of "something", that it is normally impossible not to think something, and this means that consciousness must be a continuous phenomenon, and that it assumes different states over time (Greco, 1979).

4. A change of state may be described also as information. In fact, a hypothetical uniform, never-changing system would contain more entropy than information. Information arises from changes that happen in a uniform base-flow; in other terms, each time in a uniform flow something "different" is detected or produced.

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