Language behaviour and the brain: Some fundamental questions

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This article is concerned with the study of the behaviour of biological organisms. It argues from first principles the thesis that such studies cannot be reduced to physics and chemistry in any meaningful sense and sought to be solved through the use of mathematical physics. The formalism needed for the study of organismic behaviour is the formalism that underlies the study of information processing systems. In trying to study language behaviour the emphasis is, or should be, on studying *behaviour* and not on some formal theoretical notion of *language*. Our principal concern here is with how the brain supports the integrated behaviour of any organism. In particular how does the brain support, in the case of human beings, behaviour in the language modality?

Studying language behaviour poses special problems because language behaviour cuts across all other modalities (e.g. vision, manipulation, etc.) and in a genuine sense integrates them. What is the appropriate method of analysing language behaviour to understand (and model) this integrating role of behaviour in this modality? The bulk of the article is concerned with fundamental issues that arise which we have to cope with, but we do not understand at present.

Keywords: Behaviour, brain, biological organisms, information processing systems, language.

Studying the behaviour of biological organisms

THE spectacular successes of the physical sciences during the last three centuries have given us all the impression that the ends and means of the physical sciences *define and circumscribe* the nature of scientific activity; that to study organismic behaviour we must conduct experiments much as physicists do, construct mathematical theories much as physicists do, and be able to predict as physicists do. If one is not quantifying, measuring and predicting behaviour, one is not doing science.

I think these views are based on serious misunderstandings of what scientific activity is all really about. I have discussed the reasons for my believing so on other occasions, at other places. It is not necessary to repeat all those arguments here now. But I would like to reiterate one basic point which is central to these arguments. That is, a study of the behaviour of organisms calls for categorically new kinds of explanations which the physical scientists in their study of the physical world are not concerned with at all. For, what is of fundamental importance to behavioural studies is the fact that an organism is an *agent*. It has a repertoire of actions using which it can interact with the world around it; describe, explore and manipulate this world. At the basic level, a science of organismic behaviour must concern itself with the nature of these *agentive acts* of an organism and account for them. We should be able to say what primitive structures and what primitive processes put together in what ways can give rise to the kinds of behavioural acts an organism engages in (for more details see Narasimhan[1]).

It would be a great fallacy to think that problems of agentive behaviour can be reduced to physics and chemistry, and can be solved as such in any meaningful sense. Most of our real-life encounters with the world require us to assign interpretations to the situational aspects of the world that confront us. This is equally true of the interactive behaviour of other animals. Problems that arise in interpretation are qualitatively different from problems that arise in signal processing, which are amenable to the analytical techniques of mathematical physics. Description, identification, recognition and understanding are essential aspects of interpretation assignment which cannot be solved by the standard techniques of mathematical physics, which form the foundation of the physical sciences. The formalism that is needed to study organismic behaviour is one that underlies the study of information processing systems.

The study of behaviour is firstly concerned with the articulation of information processing systems that can account for the agentive aspects of agents – that is, information processing systems that can interact with their environments and are capable of describing and manipulating them. The study of such systems is a problem in the study of computational structures and computational processes capable of realizing such behaviours. Physics and chemistry come into the picture only when we get down to the study of specific anatomical and physiological realizations of such computational structures and processes.

Behaviourally the agentive aspects of agents may be characterized in a quite natural way as follows:

An agent has a repertoire of *actions* which it can deploy for appropriately interacting with the external world. An agent has a set of *sensory interfaces* through which infor-

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mation concerning the external world and, in particular, concerning the changes caused in the external world by its own actions is available to it. An agent has a set of *motivational states* which condition the intentions or goals of the actions the agent engages in or embarks on.

At the most primitive level, an agent engages in an action to bring about a desired-for change in the state of the external world. This desired-for change is the *goal* (objective, aim, purpose or intent) of the action. Goals, in general, may require the execution of a complex *program* of actions. '*Program*' is used here in the information processing sense. A reflex would thus be a pre-wired program. Habits are already built-up programs that get executed more or less autonomously. In other cases, achieving a goal may require the deliberate formulation of a *plan* of action. That is, a program to achieve a goal may not be available readymade, but may have to be built-up either on the basis of theoretical considerations or through exploratory experiments. In either case, an agent must have available a *knowledge-base* to construct a plan of action.

Execution of a plan of action would in general be guided by the assessment of outcomes of already executed actions. Assessing the state of the environment is based on judgment; that is, the capability to gather relevant evidence, to evaluate and to arrive at valid conclusions. *Understanding* a situation consists of successful utilization of available knowledge to *assimilate* the situation, or of enlarging or modifying the knowledge-base to *accommodate* to the situation. Judgment is thus an essential aspect of understanding. The knowledge-base directly involved in arriving at judgments constitutes the *belief-structure* of an agent. The notion 'desired-for change' involves a valuation process. Hence, one must predicate a *value-system* as underlying the functioning of an agent. At the most primitive level this value-system could only be based on the innate motivational states of the agent. Subsequently, the value-system must be assumed to get elaborated through the behavioural interactions of the agent with the world and their outcomes.

These, then, are the agentive aspects of an agent that relate to language behaviour and can be talked about using language. Language behaviour also plays, of course, an essential role in the ability of an agent to exhibit many of these agentive aspects. For instance, in the case of many human beings, formulating a plan of action involves the use of language. In fact, one often rehearses one's plan of action verbally. Similarly, knowledge is available in many cases as language statements. The act of judging may involve considerable verbalizing.

In addition to dealing with these agentive aspects, the pragmatics of language behaviour is concerned with a delimited totality of situations that constitute a *world* to which the particular language relates. Natural language behaviour at the naive level relates to the situational aspects of the natural physical world as available at the (unaided) input–output interfaces of human beings.

In our natural language behaviour we tend to deal with the naïve physical world in terms of sets of agents, objects and their aspects. We have already considered the agentive aspects of agents. The physical aspects of agents and objects are characterized in terms of attributes and relations whose values and validities respectively, as applying to particular situations can be computed by the language-using agent through a subset of actions of his action repertoire. Of course, organisms could have some attribute and relationship computing mechanisms built-in as part of their pre-wired structure.

Language behaviour is used, primitively, to describe, manipulate, and explore situations of a world consisting of agents and objects with their agentive states and physical states. Natural language interaction between two human beings at the basic level then relates to discourse about, and manipulation of, some class of situations of the naive physical world, including the agentive aspects of the interacting agents. The interaction consists of making assertions about the states of objects and agents in a given situation and about the relationships between these states, commanding actions that cause events relating to the objects and agents in the situation, and asking questions about the objects, their states and the relationships between the states, about the agents and their agentive states, and so on.

Language behaviour pragmatics: Function and structure

In human beings and other animals sensori-motor behaviour is underpinned by dedicated, special-purpose mechanisms, i.e. in the visual, auditory, tactile and manipulatory modalities. These peripheral modalities deal directly with the external world in terms of the signals either directly received or directly generated by the organism. Language behaviour, however, is one step removed from these direct interfaces and deals with the outer world essentially through indirection. In this sense language behaviour is based on an abstraction from the world available to the peripheral processors. It is this aspect that makes it difficult to relate language behaviour in any simple, direct way to brain structures or their specific organizations. From a systematic study of the uses made of language behaviour and the competences that normal human beings exhibit in this modality, we have to infer indirectly the kinds of organizational supports that are needed from the information processing viewpoint.

I have been developing for over three decades an approach to the study of language behaviour which is somewhat non-standard in that it takes as its point of departure *pragmatics* rather than syntax or semantics. The argument is that in order to analyse what kinds of mechanisms are needed to underpin behaviour in a particular modality, we must first analyse what kinds of uses are made of behaviour in that modality. Functions provide an insight into structures that sub-serve these functions.

Language behaviour, like behaviour in other modalities, can be categorized into one of three metabehavioural categories: *describing*, *manipulating* and *exploring*. In the language modality the traditional terms for these categories are: *declarative*, *imperative* and *interrogative*. These linguistic classifications, however, concern themselves with the surface forms of utterances. These surface forms, in general, need not mirror directly the *behavioural intent* of the speaker in performing that speech act. A simple example is this. The surface interrogative form 'Would you mind passing the salt?', is really a request for action (that is, it is manipulatory in intent).

How are the functional categories 'describing', 'manipulating' and 'exploring' put to use in the language modality? That is, using the language modality, what kinds of descriptions are generated? What kinds of manipulations are performed? What kinds of explorations are carried out? These will tell us what kinds of structures must underlie language performatives so that these functional needs are fulfilled. We can then go on to ask how these structures are acquired or built up, for example, by a child; how these structures are represented or retained in the brain, and how these structures are made use of to generate specific behaviour in a given context or situation.

Consider first a child as a behavioural system that is capable of acquiring and using language behaviour. This behavioural system has certain well-defined and characteristic features. For instance, the system has inputs coming in from the external environment through its sensory interfaces: ears, eyes, nose, skin, etc. It has certain kinds of motor actions available to manipulate the external world. There are well-defined internal state variables that determine the internal states of the system: for example, affect states, need states, etc. These characteristic features delimit and determine the various aspects of the world available to the child. And the child's behaviour must ultimately be related to these aspects of the world. Clearly, the agentive aspects of the child and the situational aspects of the world to which his behaviour relates must be mirrored in language in some sense to make it possible for the child to use language behaviour to accomplish various things in the world, to talk about the world and about his own behaviour.

We can now elaborate our central thesis concerning the *mediating* role that language behaviour plays and how it plays this role. Our assertion is that the language-behaviour utterances (of description, command and query) can be analysed into language-behaviour schemata and language-behaviour tokens (lb-tokens) in such a way that the lb-tokens directly relate to the situational aspects forming part of the situation under discussion (we shall consider an example in detail presently). In a language community, at a given time, only a limited number of different schemata of descriptions, commands and queries is in vogue. As a child, through intimate interaction with a language community, acquires his language behaviour, what he builds up is an *interpretational system* consisting of lb-tokens and their structured relationships in terms of associations between lb-tokens among themselves via language schemata, lb-tokens and sensori-schemata, lb-tokens and motor-schemata and lb-tokens and motivational state variables.

Let us consider a simple example to illustrate the basic concepts involved in an interpretational system as outlined above.

Consider a physical situation consisting of a table with a chair in front of it. On the table is a book which is red in colour and looks heavy. It is plausible to assume the following kind of language behaviour interaction taking place between two persons about this situation.

There is something on the table.
What is the thing on the table?
A book. There is a book on the table.
What kind of a book?
A heavy book. A heavy-looking book.
What colour is it?
Red. It is red in colour.
There is something else next to the table.
Yes. A chair.
It is in front of the table.
Pick up the book on the table.
I want to see what is in the book.

In this interaction, *A book*, *the thing on the table*, *There is something on the table*, *There is a book on the table*, *Red in colour*, *Pick up the book*, *I want to see*, and similar expressions are all lb-tokens. This is because they refer to specific aspects of a situation and, therefore, can occur as utterances in themselves during a language behaviour interaction. These lb-tokens either specify a particular object (the thing on the table), a particular spatial relation between two objects (*there is something on the table*), a property (*red in colour*), an agentive aspect (*I want to see*), a command to alter the state of an object (*pick up the book*).

Now, the spatial relationship between two objects expressed by the lb-token *something is on something else*, is a situational aspect ascertained through the visual modality. Visual interface schemata are here involved, which enables one to recognize this aspect in terms of a characteristic 'support relationship' existing between two objects. A child is capable of object perception and identification, and the sensing and recognition of the support relationship in the visual modality long before he comes to learn to relate the lb-token *on the table* to a specific instance of this relationship. Similarly, the action schema associated with picking up an object is acquired long before the child learns to relate this schema to a particular occurrence of the command *Pick up the book*. In the case of a child, in the very early stages, the linking of such lb-tokens to the independently acquired visual, tactile, motor, etc., behavioural aspects has to be learnt slowly and with much effort. But as one grows more accomplished in language behaviour, this intermodality association becomes automatic. Once a child has acquired a reasonable repertoire of lb-tokens, language behaviour itself can become a potential teaching medium. That is, a language can be taught using that very language after a while.

The interpretational system, as we have described above, is a characteristic of an individual. The details of the interpretational system of a given individual could be inferred only through careful studies of the individual's behaviour in a variety of well-circumscribed and well-articulated situations, and by trying to establish correspondences between the lb-tokens in the elicited behaviour, other observed nonlinguistic aspects of behaviour, and the various situational aspects.

However, it is clear that there should be much commonality between the interpretational systems built up by the various members of a language community. For one thing, there is great commonality between their individual sensori-motor structures and motivational parameters. Consequently, the aspects of the world available at their sensori-motor interfaces should also be, by and large, common. Hence, to make communication through language possible at all, the correspondences between the lb-tokens and the situational aspects as available at the sensori-motor interfaces should also be, by and large, comparable among all the members of a language community. Thus, among these members, the details of their interpretational systems should agree to a large extent. These are just the aspects that show up as the common aspects of the language behaviour of that community. This is just another way of saying that a child builds up his interpretational system by interacting with a language community and, hence, in conformity, by and large, with the interpretational systems of the individuals of that community.

So far we have been discussing about the structures that a child, while acquiring language behaviour, builds up for himself and which support interpersonal interaction in the language modality. The questions that immediately arise are: 'How is the child able to build up these structures? What acquisition processes do we have to postulate as being involved in this?'

I have argued in detail elsewhere that *imitation*, *rehearsal*, and *analogizing* can enable a child to build up this kind of an interpretational system through interaction with a language community. The characteristics of the interaction needed to facilitate this acquisition could also be specified. And it turns out that recent studies by child-language specialists show that precisely these kinds of adult–child interactions occur in the early stages of child language acquisition (see Narasimhan[2] for further details).

Paradigmatic Language Acquisition System

A rudimentary version of a language acquisition and usage model, called PLAS (Paradigmatic Language Acquisition System), based on the ideas I have been discussing has been simulated on a computer by Sembugamoorthy (IIT, Bombay). The PLAS experiment is discussed in some detail in Narasimhan[3]. This experiment convincingly demonstrates the adequacy of imitation and analogizing to build up and use language structures of the kind I outlined earlier. The important aspect of PLAS is that it is a teachable language acquisition system and it enlarges its language understanding capability through interaction with a human teacher in the very language it is acquiring. The experiment thus provides a realistic environment for testing various aspects of language acquisition and usage. For example:

1. What preliminary structures must be available in the non-linguistic modalities to enable language acquisition?
2. What processes must be postulated to support language acquisition?
3. What kinds of learning environments should be made available to enable language acquisition?
4. What additional processes must be postulated to enable language usage in a conversational mode? And so on.

I would like to summarize what we have been able to learn from the behaviour of this very rudimentary version of PLAS. What are the major gaps in our knowledge? In what ways should PLAS be augmented in order to realize a more adequate performance?

The first serious inadequacy in PLAS is that its sensori-motor structures are not articulated at all. Currently we know very little about the nature of these structures. Recall our earlier illustration of assigning an interpretation to *the book is on the table* in terms of the recognition in the visual modality of a certain characteristic support relationship between the book and the table under consideration. So the schema *something is on something else* must be linked to the visual sensori structure that relates to the perception of this support relationship. We do not know at present what is the nature of these sensori structures.

Analogously, the schema *pick up something* must be related to the motor structures that accomplish this act. It would then enable the system to execute the commands *pick up the pen* and *pick up the pencil* by performing the motor act with the different objects denoted in each case.

Notice also that in order to interpret and execute the command *pick up the pencil and place it on the table*, the motor structures relating to the acts *pick up x* and *place x on something*, and the visual structure relating to the recognition of the support relationship *something is on something else*, should all be interlinked among themselves and also with the corresponding language structures.

It is essential that we try to understand how to go about modelling at the computational level this vision-motor-language co-ordination. I do not know whether neuroanatomy and neurophysiology will be able to provide any assistance at this stage in tackling this problem.

So far we have been talking about static spatial relationships. But in order to understand events and relationships between events we must be able to cope with time relationships. How does the child come to understand the meanings of terms like *before*, *after*, *first*, *next*, *now*, *later*, *earlier*, and so on? What kind of primitive machinery is needed to deal with the temporal dimension?

A little consideration would show that viable language behaviour even at the naïve level requires the capability for naïve theorizing (i.e. going from particular statements to general formulations) and naïve inferring (i.e. going from general statements to particular instances of them). Are new behavioural principles involved here?

Lastly, and perhaps most importantly, behaviour modelling must integrate the affect–motivation dimension with sensori-motor language structures. Currently, we have no idea how to go about this. It is my view that selectional and sequencing aspects of behaviour cannot be meaningfully modelled without taking into account the affect and motivation.

Language behaviour: Cognitive considerations

Schemata and memory structures

We have been developing the thesis that informal natural language behaviour is based on the building up and use of a particular kind of interpretational system made up of language expressions and schemata with associative linkages to schemata and structures related to other (non-linguistic) modalities. Thus, inter-modality associations form an essential basis for language behaviour acquisition and use. To develop this thesis in further testable detail we would have to concern ourselves with three aspects in greater depth: (i) the nature of language schemata; (ii) the nature of the inter-modality associative linkages; and (iii) the processes that are concerned with building up the language schemata.

It would take us too far outside the scope of our present discussion to analyse these aspects further here. Aspects (i) and (iii) are discussed in some detail in Narasimhan[3]. From the computational point of view, little work has been done on aspect (ii). This is an issue that requires serious study before we can construct realistic models of language behaviour acquisition and usage.

Our long-term goal is to work out viable computational models of language behaviour in order to account for its characterizing features and to understand, in general, how human beings are able to make use of it in the ways they actually do. Modelling issues can be conveniently divided into two groups: *representational* issues and *control* issues. Representational issues relate to the kinds of structures that underpin behaviour and the manner of internal representation of these structures. Control issues relate to the realization of some specific behaviour at a given moment of time based on the constraints delimited by the situational context eliciting that particular behaviour. With respect to both behaviour representation and behaviour control at the neural-level, our present understanding of the real-life situation is practically nil.

Control issues become dominant when we move from modelling the production of isolated utterances to modelling discourse. In ordinary daily living, the following discourse forms would seem to be of central importance:

1. Conversation (also, as a variant, monologue);
2. Describing
   an actual situation out there,
   or a potential/desired situation;
3. Instructing
   another through a
   procedure to perform a task successfully;
4. Narrating
   a story, a sample of one's life experience, and so on.

Children go through well-defined development stages in mastering these discourse forms. We do not, at present, have well-articulated computational models to account for the way these discourse forms are handled in real life.

For modelling language behaviour, a more serious problem is coming to grips with *instructability*. Through instruction we can add knowledge and also regulate control. And do these not only in the language modality, but across modalities. How is this achieved?

The introduction of computer technology is enabling us to probe the processes involved in language usage along dimensions which would have been difficult to contemplate before the advent of computers. For example, the phenomenology associated with language using differs depending on the mode of use – speaking, writing, translating – apart from its use in the discourse forms we earlier considered. There is, a priori, no reason to assume that, despite the differences in their outward forms, these modes of language usage can all be modelled – or accounted for, or explained – in terms of a unitary framework – for example, in terms of a standard notion 'grammar', or of a single set of computational processes. It would seem quite plausible to argue that language usage is not one thing but many different things. Hence, a plurality of frameworks may be needed to model the varieties of language usages appropriately.

Figure 1 is a schematic of the four language actions associated with speaking and writing, namely speaking, writing, listening and reading. The language objects which are the outputs of *expression* are explicitly shown in terms of their constituents. Considering human beings as computational (i.e. information processing) systems engaging in these language actions, several issues arise for study. We become aware of these issues when we try to program computers to mimic these language actions of humans.

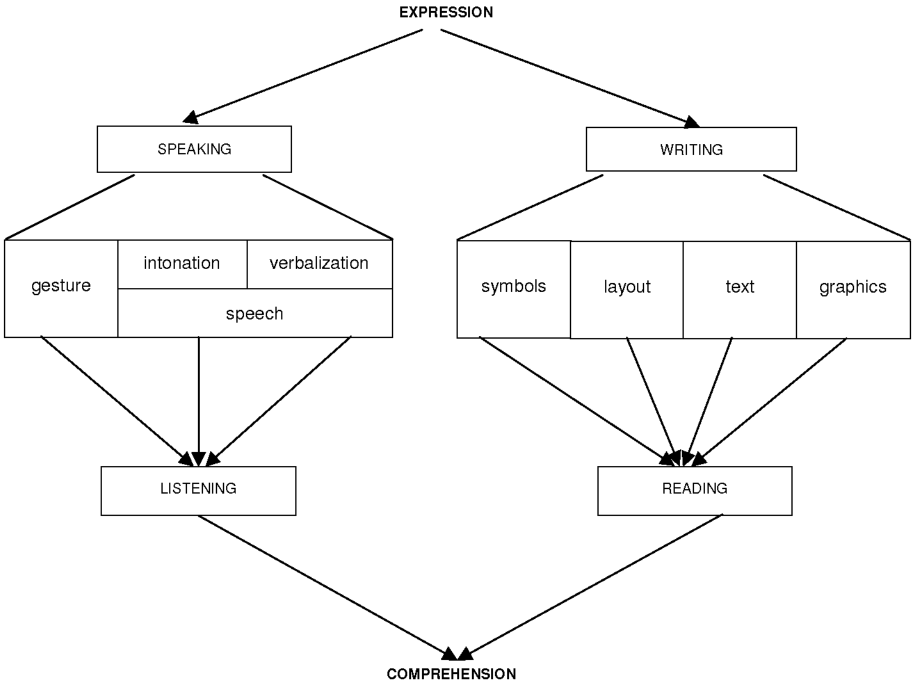

Figure 1. Language behaviour acts: Speaking, writing, listening, reading.

It is not clear, a priori, that speaking a language and writing it are not distinct skills that are served by quite distinct mechanisms at the behavioural level. In other words, distinct subsystems each incorporating a different representation of the concerned language – say, English or Hindi – at the behavioural level may be involved in speaking and writing. It is plausible to argue such a thesis because 'oral' speech behaviour is acquired by everyone without any special effort or tuition, while 'literate' writing capability requires formal tuition (or self-tuition), much drill and practice.

Summarizing, in general, we should not ask 'what is the correct internal representation of a language, say, English?' Rather, we should want to work out effective representations for the task on hand: speaking, writing, translating and so forth. We should experiment with many 'grammars', for example, to determine which one suits each task best.

Consider now the parts of the system in Figure 1 termed 'Expression' and 'Comprehension'. What is the representational-level characterization of these? The standard approach is to say: 'First there are thoughts or ideas. These are then expressed in language, in English, Hindi, and so on'. How are thoughts or ideas internally represented? To claim that they are represented in the 'language of thought' is not to say very much at all. For, is this 'language of thought' like any other natural language? What is its vocabulary? What is its grammar? Are these pre-wired into us? Is going from the 'language of thought' to a natural language, say English, a translation process analogous to translating from English to Hindi? Clearly, this translation process cannot be pre-wired. How is it acquired then? What are the relationships between the processes involved in a child's acquiring English, say, and its acquiring this internal translation process from the 'language of thought' to English?

Analogous questions arise in characterizing the part of the system labelled 'Comprehension'. Are the representational aspects in 'Expression' and 'Comprehension' the same? If not, we are confronted with yet another translation process! Notice how all the various subsystems are brought into interaction in performing the following tasks:

Task 1: Listen to what I say in Hindi and repeat it in your own words in Hindi.
Task 1a: Listen to what I say in Hindi and repeat it in English.
Task 2: Read what I have written in Hindi and rewrite it in Hindi in your own words.
Task 2a: Read what I have written in Hindi and rewrite it in English.

Clearly, the issues we have raised above are genuine and need to be addressed whether we wish to theorize about how people cope with these tasks, or whether we wish to program computers to mimic these capabilities of people.

Remembering and recalling

We tend to look upon 'remembering' and 'recalling' as somewhat analogous to 'storage' and 'retrieval'. In the real, physical world we may store information in a book, on computer tapes, in computer memory/storage; or we may store material items in a cabinet; we may store letters in pigeon-holes. Retrieval is then the reverse process. We go searching for an item when in need of it, find where it is stored and retrieve it.

'Remembering' construed as 'storage' also raises other deeper issues. We remember our experiences; we remember a picture, a face, a piece of music; we remember a word, a name, a variety of language expressions; we remember rules and procedures for solving problems, or specific puzzles. In each of these cases, what is it that is stored? In remembering a face, is it something like a photograph of the face that is stored? Who looks at this photograph stored inside the brain and interprets it, draws inferences from it, and so on? There is much less of the brain available now to do all these!

In the case of language, are individual words and expressions stored in some form? As in a dictionary, for example? Is there only a single entry for a given word, or are there multiple entries? Would it be possible to destroy selectively specific entries, like tearing a page off a dictionary? Would that destroy one's capacity to use the particular expression or word, or understand it? In aphasia, highly specific deficiencies of these kinds do not occur. Attempts to locate specific memory traces in the cortex have all been unsuccessful.

All these negative results are highly counterintuitive and puzzling, for it is difficult for us to understand how highly complex symbolic activities can be learned and retained in the absence of very particularized internal representations of these symbolic details. And if they are to be there, what is the alphabet that is used for building up and preserving these internal representations? Quite clearly, either we are asking the wrong sorts of questions, or there are fundamental gaps in our understanding of the processes and mechanisms that underlie remembering and recall.

Clearly, there are vast gaps in our understanding of the brain mechanisms that support complex symbolic behaviour, such as our use of language. We seem to lack an appropriate language even to formulate our problem in. Our everyday linguistic conventions lead us to talk about the operations of our mind as if they were the results of the 'actions' of an autonomous agent residing inside us. Clearly, this is a useless metaphor. On the other hand, in science, as in other spheres, we have to make use of analogies in the beginning stages if we want to make any headway at all. Our dilemma is that we do not have as yet any serviceable analogy.

The basic problems we have to address ourselves to are: determining what kinds of information are stored ('retained' is probably a more neutral term) and how this information is represented internally. It is quite clear that a good deal of our knowledge is skill-based. In such cases we can at least theoretically argue that the internal representations must be in terms of action sequences (or complexes) that enable us to exercise these skills. Although it is plausible to argue that a good part of our memory is based on our action mechanisms, it is difficult to account for everything in these terms. For example, what action mechanisms could we invoke to account for eidetic imagery?

Language behaviour disorders

Developmental phenomena specify one set of constraints which any acceptable model of language behaviour must satisfy. We looked at some aspects of these constraints in the last section. Analogously, language behaviour disorders specify another set of constraints which, again, any modelling attempt should take into account. Studying the disruptions of behaviour in any modality is one powerful method of exploring the structures and processes that support normal behaviour in that modality. In the context of language behaviour such distruptions, of course, result in the various categories of aphasia.

Although systematic studies of language behaviour disorders arising out of brain damage date back to over a century, our understanding of these behavioural disorders is fragmentary and unsatisfactory. The principal reason for this is that language behaviour, as we saw earlier, is a second-signalling system, i.e. it is one step removed from the information about the real world available at the peripheral (i.e. sensory-motor) interfaces and is based on an abstraction of this information. And in this role it impinges on all aspects and all modalities of behaviour of a human being. Consequently, disorders in language behaviour give rise to consequences that affect the concerned human being in ways that are not easy to categorize. Because of this we do not have a satisfactory and universally accepted classification of these disorders into discernible types. Most classifications in current use are highly overlapping ones.

It is important to emphasize that aphasias do not imply total 'loss' of language or specific units of language. As Lenneberg[4] has emphasized: 'Neither discrete words, nor discrete grammatical rules are neatly eliminated from the store of skills …. But some physiological processes relating to activating, monitoring or processing of speech are deranged …'.

Clinical tests administered for establishing, classifying or exploring aphasias have traditionally been confined to the phonological, syntactic and semantic dimensions. But more recently, aphasia studies have begun to investigate disorders in the pragmatics dimension[5]. It is important, also, to observe deviant behaviour in its natural setting, rather than exclusively under test conditions, in order to understand the nature of the functional deficits. It should be of great interest to study systematically, problems of the following kind: how effective is an aphasic in planning a sequence of actions; in judging (i.e. gathering relevant evidence and drawing a valid conclusion); in role playing; in providing instructions to another to achieve an end (to reach a place, to play a game, to solve a puzzle, etc.)? Does an aphasic experience difficulties in looking at a situation from another person's point of view? Are there difficulties in understanding or using language expressions relating to specific situational aspects? For example, it is well-known that aphasia for names shows up as a specific disorder. But what about relational expressions – spatial relations, temporal relations? Answers to questions like these are likely to throw more light on structures and processes that support language behaviour in normal circumstances.

Concluding remarks

Serious study of language behaviour calls for an interdisciplinary effort. Neurologists, psychologists, child development specialists, specialists in aphasia and related language disorders, and computer scientists interested in behaviour modelling must work together. The study of language behaviour is intrinsically complicated by the fact that unlike the sensori-motor modalities, there is no identifiable part of the brain that is dedicated exclusively to language modality. Language behaviour cuts across all modalities and in a genuine sense integrates them. Therefore, it is not possible to isolate language behaviour and study it independently. And for the same reason, when disruptions in language behaviour occur, they tend to affect the functioning of the whole behavioural system in complex ways.

Before we can hope to characterize the various types of aphasia in a discriminating manner in terms of the language behaviour functions that are disrupted, we must have a more satisfactorily worked out computational model of normal, naïve language behaviour.

In order to understand the essential features of language behaviour, we must first be careful not to confuse it with speech, or grammar, or literacy (reading and writing), or abstract symbolic operations. It seems to me that many of the tests for aphasia in current use suffer from precisely these kinds of confusion. I think we are likely to learn more about the functional deficits associated with aphasia if we can study it in circumstances where one or more of these confusing dimensions are naturally absent.

Brain is preeminently an organ that supports the integrated behaviour of an organism. Theories of behaviour in any modality must be built up in terms of information processing structures and processes specific to that modality. In the recent past, through the use of computer simulation techniques promising partial theories have been formulated for some modalities – especially for vision. But, as pointed out earlier, we have no idea at present how to model in biologically relevant ways inter-modality information transfer and behaviour integration. To model or theorize about language behaviour in a non-trivial way, we have necessarily to confront precisely this central issue of inter-modality information transfer and integration of behaviour, i.e. how language behaviour interfaces with behaviour in the other modalities and integrates them. Our problem then is not one of determining how to move forward, but how to get started.

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