William H. Edmondson, Cognitive Science Research Centre, School of Computer Science,
The University of Birmingham, Edgbaston, B15 2TT, UK. w.h.edmondson@cs.bham.ac.uk

General Cognitive Principles and the Structure of Behaviour

> *The study of biologically necessary properties of language is a part of natural science: its concern is to determine one aspect of human genetics, namely, the nature of the language faculty. Perhaps the effort is misguided. We might discover that there is no language faculty, but only some general modes of learning applied to language or anything else. If so, then universal grammar in my sense is vacuous, in that its questions will find no answers apart from general cognitive principles.* Noam Chomsky, *Rules and Representations*, 1980:29.

1.0 Introduction

The tenor of the quotation above, of its location within Chomsky's work, and of its theme within the generative enterprise, is clear – there can be no such general cognitive principles (which is just as well, given the quantity of work predicated on this assumption). There is also, however, a sense of challenge – universal grammar could be undermined, if not rendered vacuous, by the development of an alternative basis of explanation centred on general cognitive principles. That such principles have not been set out already, along with relevant explanations of, for example, linguistic data, is not necessarily because they *cannot* be but plausibly just because they *have not* been yet (the work is difficult). This paper lists six general principles (identified as part of a larger programme of work) and discusses the first three. The central idea is that behaviour is governed by the sequential imperative, a concept which is explained and illustrated.

1.1 Preliminaries

Three preliminary issues need some brief discussion before the general principles can be introduced: what are the discovery procedures for such principles?; what is the number of principles?; are the principles explanatory or descriptive?

1.1.1 *Discovery procedures* for general cognitive principles cannot reasonably be established. The principles are introduced below *ex cæruleo* but this does not, of course, imply casualness. The last two are fairly recent crystalizations, the first two have emerged from directed research and experiment over more than a decade (cf. Edmondson 1986).

1.1.2 *The six principles* are put forward as a coherent set which, it is hoped, may strike the reader as blindingly plausible. But why six? In fact the number is neither predictable or immutable. A simple bracketing process (2 would be incredible; 42 would be absurd) quickly gives a range of 3 - 10 as reasonable, with mid-values 'feeling about right'.

1.1.3 *Explanation and description* are usually considered to be terms with little overlap of meaning; both offer accounts of phenomena but these are evaluated quite differently. Explanations are 'theory based', have predictive value, and locate the phenomena concerned within a larger scheme of things. Descriptions – often perjoratively coupled with 'mere' – are supposedly limited in value because of a lack of 'predictive power' or theoretical basis. The distinction is specious. Explanation is the sense one gets when a phenomenon is coherently related, by the account given, to a range of other phenomena. The broader the range the more profound the explanation. The account which serves to provide the relation can take any one (or more) of a number of forms – e.g. logic, theory, or description. The problem with description, such as it is, derives from the often limited range of phenomena brought into consideration with the phenomenon of interest. However, this is not a necessary impoverishment and richly coherent and broad-ranging description will provide as much explanatory power as any theory; achieving such a description is not straightforward. The general cognitive principles are explanatory and descriptive.

1.2 The General Cognitive Principles

GCP1 Sequentiality in behaviour is forced physiologically.
Corollary 1 Sequence penetrates the corporeal boundary.
Corollary 2 Sequence is semiotically free.

GCP2 Cognitive entities are i) inherently atemporal, & ii) dual in nature.

GCP3 Behaviour is sequencing; perception is de-sequencing.

GCP4 Learning serves the sequential imperative.

GCP5 Attention is the management of the processes of sequencing and de-sequencing.

GCP6 Thought is the production of cognitive entities.

1.3 Three General Cognitive Principles

The listing of six principles is for completeness, and to indicate something of the range of behaviour and cognitive phenomena covered. Our purpose here is to establish that a case might be made that such principles can serve as the basis for a comprehensive explanation of cognitive activity, including linguistic activity. The first three principles suffice for this.

2 The Sequential Imperative – I

Sequentiality in behaviour is forced physiologically. GCP1
Sequence penetrates the corporeal boundary. Cor.1
Sequence is semiotically free. Cor.2

The essence of the first general cognitive principle is that an organism has no choice but to do things in sequence. Choice exists in the exploitation of sequentiality. Through the first principle we can recognize and describe the pervasive significance of sequentiality in human behaviour, whilst simultaneously recognizing where and why sequentiality in behaviour is misunderstood. It is noteworthy that the first general *cognitive* principle appears initially not to be concerned with cognitive issues, but rather with physiological constraints on behaviour. For our appraisal of the first principle we need an analysis of these constraints.

2.1 Co-ordinated sequentiality

The successful management of any skeleto-muscular system – in homeostasis, or in intended movement – requires the constant control of the activity of many dozens of muscles. Patterns of muscle contractions will be required to stand upright, or to hold one's chin in one's hand, or whatever. Similarly, patterns of muscle activity can surface as observable actions – walking, shaving, etc. We describe such muscle control as *co-ordinated*, regardless of whether or not we can, as an observer, see the patterns of muscle activity as physical action. Co-ordination is the successful organization of simultaneous and sequential muscle activity.

2.2 Origins of sequentiality

Our concern here is the significance, or otherwise, of co-ordinated sequentiality. Clearly, without sequential patterns of muscular activity a creature would cease to be; without visible muscular activity the observer might be forgiven for doubting life.[1] In order to do anything at all sequences of muscle action are required. The physiological necessity, nay *imperative*, for such patterning of action operates regardless of size or species – movement is being. But where does the sequentiality arise?

Consider a kitchen sink containing an assortment of implements and dishes in the soapy water, with someone washing these items. One by one the objects are cleaned and rinsed and arranged in piles, or racks, or whatever, to dry. This is true regardless of whether or not we are merely 'going through the motions', or are performing the task meticulously. What is also true, in either case, is that the motions are necessarily sequenced, and that *the sequence doesn't matter*. We will return below to the possibility of interpreting a sequence as significant but for the moment our concern is that in regard to something like washing dishes

[1] In point of fact the requirement is not inherently restricted to muscular activity – that restriction is made here for expository simplicity. The general statement that patterning of action indicates life remains true, even 'down to' the scale of metabolic activity in cellular organisms.

our physiology forces sequentiality in an activity which is not obviously constrained by its nature to have that sequence.

2.2.1 *Inherent sequence.* How can we make sense of the above claim? The washing of a plate, or spoon, or glass, requires a sequence we can conveniently describe as 'wet –> wash –> rinse –> dry'. This has to be applied to all the objects, of course, but this application itself does not have to follow any specific sequence; a dishwasher applies the sequence to all the objects at once. Washing dishes is not a special example, and in such cases the sequence appears to be imposed as the consequence of possessing a limited number of arms and hands. Although this is the first step toward understanding the sequential imperative (see (2.3.2) below), the notion of physiological limits is not the whole story.

If we return to the dish-washer example briefly we can acknowledge, and label for future reference, the sequentiality which reflects some aspect of the activity itself. The 'wet –> wash –> rinse –> dry' sequence is inherent in the activity of washing, and will surface one way or another because no amount of re-design of the physiology will get rid of it. The machine succeeds better than ever we could, and still has to go through the sequence. Furthermore, there is no way around such an *inherent sequence* through redefining the notion of 'washing' or whatever (we end up talking about something else).

2.2.2 *Special purpose solutions.* Some activities may reflect specially evolved behaviours &/or purpose-built articulators (and neural controls), for example myriapod locomotion and reflex actions in vertebrates. These are local solutions to specific problems and they are in effect instances of inherent sequence built into the physiology (not the events, or physical situation for the action).

2.2.3 *Inherent sequentiality.* There is another external constraint on the behaviour of any creature which forces sequentiality. Here however, instead of detecting the existence of an inherent sequence, what we find is *inherent sequentiality*. This is to say, sequentiality, but not a specific sequence, is forced by the situation. Suppose one wishes to look around – which way do you turn first? The fact of the situation is that one has to turn one way first, one cannot turn both ways simultaneously. Although a completely different visual system might help (but it does so by removing the need to turn, not by making simultaneous bi-directional turning possible), the visual search situation is hardly unique – you cannot walk simultaneously to the left and to the right, or climb a tree and hide in its roots, etc. We can note, then, that as with the inherent sequence in washing the problem is not a physiological lack of articulators. There is one further difference between inherent sequentiality and inherent sequence which needs to be stressed – the former gives rise to arbitrary sequences, the latter does not.

2.3 Physiological constraints

By way of an elaboration of the point just made about inherent sequentiality consider now an unusual requirement of a person, even a contortionist: to eat a banana whilst drinking from a stream, remaining dry, and tying both pairs of shoelaces. One's immediate response is that this is just like turning left and right simultaneously. It is not; it is really a question of physiological limitation. Some minor genetic adjustments here and there – a couple of mouths, more arms, a longer neck. That should do it – or remarkable (unbelievable?) skill as a contortionist. We can see that the physics of the situation does not prevent the simultaneity. There is no inherent sequentiality, and certainly no inherent sequence. But it is here that we find the sequential imperative at its strongest, and most intriguing.

2.3.1 *An evolutionary perspective.* We can now reconsider the significance of special-purpose articulators in the general scheme of beings. Provided a creature only has a limited number of things to do it would seem to be a reasonable design strategy to propose that specific actions or tasks have specific articulators. Build in some inherent sequences and the creature becomes entirely stimulus driven, and perhaps can even function fairly well. Add a short life-cycle, great fecundity, and modest energy requirements and success seems assured. But the reality is that the success is very circumscribed. The inherent sequences involved are not well suited for coping with novel situations. There is an alternative of course.

2.3.2 *General purpose articulators.* The alternative avoids ever increasing numbers of special-purpose responses, articulators, and so forth, and instead provides a smaller number of general purpose articulators. The range of behaviours required of such articulators is provided through the sequential imperative. You can make a limited number of articulators do a great many things, provided you do them in sequence – any sequence will do, just so long as the pressure to do things simultaneously is avoidable.[2] In fact, the value of such generalization is seriously compromised if specific sequences are involved – one is back with the physiological inherent sequences.

2.4 Sequentiality in behaviour is forced physiologically

Let us return again to the kitchen sink, and to the claims that the motions of interest are necessarily sequenced and the sequence does not matter. What we have is a set of articulators of general purpose utility, being employed in a specific task (the inherent sequence of which we have recognized, and can ignore for the moment). Sequentiality is forced because we cannot do everything at once.

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[2] This situation is faced by designers of automated machine tools. A flexible tool can select from a range of drill bits to machine a complex part – drilling holes in sequence, but reprogrammable. An inflexible tool with a set of different drills in a particular configuration can produce a fixed pattern of holes in just one operation, but it may require radical alteration to produce a different result.

The claim is a subtle one. For any organism there is a behavioural domain bordered in part by inherent sequence and inherent sequentiality. Also defining this domain is the set of articulators available for simultaneous activity. A quadruped can operate its limbs in pairs of co-ordinated activity; a squirrel can hold a nut in its two front paws and co-ordinate simultaneous activity in juxtaposing the nut and teeth. Another border is cognitively determined: attention provides a simultaneous or enduring context for action. Thus a person washing dishes is doing just that, and nothing more, and for as long as it takes. The space so defined by these borders is one where the organism has to organize behaviour sequentially – it has no choice. For the person at the sink this behavioural space is defined by the facts of the unitary task, the articulators available, and the inherent sequence of the operation. *The sequential imperative forces the fragmentation of the task into a sequence of smaller tasks each of which is manageable physiologically, but it cannot specify the sequence and so the sequence remains arbitrary.*

2.5 The corollaries

We are now part-way to understanding the significance of sequentiality in behaviour. To complete the account we must consider the corollaries. We begin with the first of these.

2.5.1 *Sequence penetrates the corporeal boundary.* Surely school-children the world over have discovered the imponderable philosophical question "How do I know that the green I see in my head when I see something green is the same as the green you see in your head when you see that green thing?" Of course, it is the basic question we are dealing with not the specifics of greenness, and perhaps the extensiveness of the discovery is exaggerated. It seems likely, however, that the essential core of the question – the link between the 'external' world and the 'internal' world – is something many children and adults stumble across, even if their interest falters as they struggle with the all too obvious answer.

The curious thing is, however, that there is a positive answer available, one which is required if any sort of behaviour is to be possible at all, and one which seems oddly ignored. The answer is that *sequence penetrates the corporeal boundary.* An alternative phraseology might help appreciation of the point: 'a sequence within is that same sequence without'. Consider the following: if A comes before B, which in turn precedes C then, provided there are no doubts about the evidence, or the perception of the events, a person can guarantee that their *internal* representation of that sequence – *as a sequence* – is the same as another observer's *internal* representation.

There is more. Sequentiality is the only property of objects and behaviour on which one can depend when it comes to transforming intention into action, or action into percept. This bi-directional dependability is vital. If, as has been argued earlier, sequentiality makes possible general purpose behaviour with a restricted set of articulators, then an additional design requirement must be met. It must be possible to guarantee that co-ordinated sequential muscular activity matches the requirements or intentions of the actor. That guarantee *can* be

provided when those requirements or intentions are cast internally in sequential form. Furthermore, the intention can be checked against the reality because the external sequence can be re-internalized as a sequence. Nothing else can provide the guarantee. It is therefore no accident that the sequential imperative depends for its realization as a motivator on the existence of a specific property of organisms: their occupation of space-time. We would have had to have imposed such a requirement had we not independently recognized that the conditions required were already operative.

2.5.2 *Sequence is semiotically free.* The shift from a physiological perspective to a cognitive one becomes even more pronounced when we reflect on this corollary. The previous discussion brought us to recognize the value of internal sequences as representations of external sequences (and vice versa). We need now to recognize that *sequentiality* needs no other motivation; *sequence* really can be arbitrary. But the implication of this is tremendous – sequence is free, semiotically, to serve other purposes, to be imbued with whatever significance or value we wish.[3] We will explore this in later sections.

2.6 Summary of the first principle

Let us return again to the kitchen sink. Whilst meeting the demands of the inherent sequence 'wet –> wash –> rinse –> dry' we are free to pick the items in any order. This can be random, but it could equally be driven by the sorts of consideration mentioned earlier. It could even be driven by other factors, for example a selection of the 'best' crystal glassware to be washed first, followed by heavy cast-iron pots and pans, placed on top of the glassware to dry, could be interpreted as indicating hostility, dislike of crystal, ignorance, or stupidity (to list just four). The importance of this is not that there is a *right* interpretation, but rather that the sequence is available to be imbued with meaning by all parties – washer and watcher alike. Sequentiality is forced so sequence is free.

The section opened with the suggestion that we could learn from a consideration of GCP1 where and why the rôle of sequentiality in behaviour is misunderstood. The semiotic freedom of sequence is perhaps the single most obvious illustration of this point. If we fail to recognize the exploitation of sequentiality which is itself motivated elsewhere then we have, unlike Nature, missed a trick. However, the more general point is that the rôle of sequentiality in human behaviour is at once simpler and more complex than we might at first have supposed. In the next section we will look more closely at the ways in which sequence gets exploited, and at the implications of this for our emerging appreciation of the *cognitive* implications of the sequential imperative.

[3] Those who like to think ahead might note that this is equivalent to Hockett's "duality of patterning" design feature.

3 The Sequential Imperative – II

GCP2
Cognitive entities are
i) inherently atemporal;
ii) dual in nature.

The focus in this section is on time and sequence, and our goal is a general understanding of the second general cognitive principle in terms of the relationship between time and sequence. For our example we turn away from the kitchen sink to another, equally quotidian, activity – making a cup of tea.

3.1 Temporal structures in cognitive entities

The essential question is whether or not it is possible to discern temporal structures in cognitive entities such as a belief in God, desire for a cup of tea, recognition of a face, knowledge of the squares of single digit numbers, memory of a street address, and so forth. This question can be elaborated as two more questions: are there reasons to suppose that evidence of temporal structures in neuronal activity must also be construed as evidence of temporal structures in cognitive entities?; are there reasons why cognitive structures must necessarily have (or not have) temporal structures?

3.1.1 I will asssume without debate (and I believe uncontroversially) that neurological activity does not imply temporal structures in cognitive entities contingent on those neural temporal structures. This is surely unsurprising for something like recognition of a face. Such 'objects', it could be argued, are themselves enduring, so any temporal structures discernible are artefacts of perception. The situation is not significantly different when the object does indeed change over time. My concept of my garden, for example, is not *itself* something which has an annual cycle, even if it does constitute a representation of such temporal activity. *Mutatis mutandis*, my concept of boiling an egg does not itself bubble and simmer for 4.5 mins (approx.).

The biology is uncoupled temporally from the cognitive entities contingent upon it.[4] This physiologically driven viewpoint provides the first step in answering the two part interpretation of our original question. Temporal structures in the neuronal activity do not imply any such structures in cognitive entities. *Cognitive entities* cannot be anything but timeless and enduring – they *are inherently atemporal*.[5]

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[4] The management of space-time, for the purposes of thinking and conveying, is the mind-body solution – the 'problem', insofar as there is one, relates to our inability to recognize that the discussion is not really about 'levels' of description, but rather about relevant dimensions of description and discontinuities in the scales of these dimensions. GCP1 & GCP2, in particular provide the basis for the solution.

[5] Processes such as learning and thinking – i.e. the creation or modification of cognitive entities – will be addressed in another paper.

3.2 Non-temporal structures in cognitive entities

A widely held view of cognitive structures is that a – perhaps the – dominant organizing principle is the hierarchy. Hierarchical structures are uncontroversially posited, or 'detected', ubiquitously as ubiquitous. The tree-structure so widely encountered, with its root at the top, is as necessary to the cognitive scientist as is the hammer to the geologist, and pencil and paper to the mathematician. This fondness for hierarchical structures is, in my view, unfortunate, because it is misguided (and see below in section 4).

3.2.1 *Sequencibility.* The most significant thing we can say about cognitive entities – apart from and because of the fact of their enduring atemporal nature – is that they must be sequencible. For this to be possible only one simple structural property is required – cognitive entities must have other cognitive entities as their constituent parts. It is *not* required that any further claim be made about the nature of such entities or about more complex structures. *The simple duality of an entity and its parts is sufficient; cognitive entities are at once unitary and comprised of constituent parts (which are themselves cognitive entities).*

This duality makes it possible for the sequential imperative to do useful work; duality provides sequencibility. Furthermore, given that the components of cognitive entities will also be cognitive entities the way is open to the construction of very finely detailed sequences for individual cognitive entities, sequences which can be manifested in observable behaviour.[6] The duality of cognitive entities, coupled with the sequential imperative, provides for the temporal fine structure which cannot be present in the cognitive entities themselves but which is present in behaviour. This is elaborated below and in later (sub-)sections.

3.2.2 *Hierarchies.* A significant by-product of the effect of the sequential imperative on cognitive entities is the generation of structures which appear to be principles of organization – e.g. hierarchies – but which are in fact artefacts of behaviour. A simple illustration is appropriate here. A book is typically organized as a sequence of sections, each with a sequence of chapters, each with a sequence of headings, each with a sequence of paragraphs... sentences... words. This tidy hierarchical organization is not inherent cognitively but rather is the product of the sequential imperative acting on unordered cognitive entities and their constituents and their constituents.... Note that the claim is not that hierarchies cannot be found in the observable behaviour, only that this is no more than a behavioural artefact. The organization of the cognitive precursors of behaviour cannot be simply 'read-off' the observable activity (see also section 4).

3.3 GCP2 and observable behaviour

It is assumed that the neurophysiology does not undermine the atemporal nature of cognitive entities (the physiology is uncoupled from cognition in the temporal domain). The balancing

[6] One needs to assume, of course, that the division into ever 'smaller' entities has a natural limit.

property of these entities is a basic structural property – duality – and this permits the sequential imperative to organize behaviour in time. We will now take some space to illustrate with one example the various points made so far.

3.3.1 *Quotidian example.* We return to the kitchen to make a cup of tea. The end product consists of a cup or mug containing a hot infusion of tea, without tea-leaves but with a splash of milk and a teaspoon of sugar (let us presume). How is this achieved? The cup of tea, as an entity, has some sub-components – the infusion, the milk, the sugar, the cup. Each of these components has sub-components, but here some inherent sequence and some inherent sequentiality may also be involved. The infusion, for example, has inherently sequenced sub-components – boiling the water, steeping the tea, separating the tea-leaves from the infusion. The milk component typically comprises some inherently sequenced sub-components – locating the milk supply, drawing off the required quantity, replacing the milk supply in its original location; likewise the sugar. The 'cup' might have two physical sub-components (cup and saucer) and these have to be brought into the correct physical juxtaposition. This will probably reflect inherent sequentiality, not because either cup or saucer *must* be retrieved first but because the two have to be brought together at some time, from a state where they were not, and only occasionally will this be achieved by simultaneous actions independently on both cup and saucer. Clearly some of these sub-components will also involve sub-components – kettle, water-supply, heat, tea-caddy, tea-spoon, milk-bottle, sugar-jar, tea-strainer,... – with perhaps some inherent sequence and sequentiality. This could all be explored in some detail but that would distract us from the main purpose of the example. Likewise it is possible to consider other components of which the tea-making is just a sub-component – preparing a meal, entertaining a friend,... – and these too are not germane.

When considering the activity of tea-making we should guard against any tendency to attribute temporal organization of behaviour to the cognitive precursors of those behaviours. For example, the concept of a cup of tea with milk does not itself have temporal structures dependent upon retrieval of milk from a milk-bottle in a refrigerator. It does have duality and this permits temporal structure in behaviour. We should also guard against false attribution of significance to sequentiality – for example inherent sequentiality can easily be misconstrued as inherent sequence. Our concern here is duality (sequencibility) and the atemporal nature of cognitive entities.

3.3.2 *The process.* So, what actually happens when we 'make a cup of tea'? Water must be brought to boiling point and brought into contact with the tea-leaves. This does not have to be done before, or after, any of the other components are executed. A cup must be located. Milk and sugar must be located, measured out and the supplies returned to their usual place (or not). These too do not have to be done before or after anything else. However, all of these things do have to be done, and the sequential imperative ensures that the behaviour is sequenced one way or another – just so that we *can* do things, and so that we can know that what we are

doing is what we intended (or not) [GCP1: Cor.1]. However, the lack of constraints provides semiotic freedom [GCP1: Cor.2] and so orderings *may* become habitual and meaningful, and thus they often end up doing so. There are many possibilities - and this is just the point.

3.3.2.1 One possibility is to proceed as follows: Fill kettle and set to boil, find mug and put on work-surface, wash out tea-pot and hang on spout of kettle to be heated by steam, take milk-bottle from refrigerator and place near mug, take spoon in hand, locate tea-caddy open it and place spoon inside, place caddy near mug, locate sugar-jar and place near mug, remove tea-pot from kettle-spout, drain and place near mug, spoon tea from caddy into tea-pot leaving spoon in tea-pot, add boiling water to tea and stir, remove spoon and put in place tea-pot lid (still holding spoon), open sugar jar and put spoonful of sugar in mug leaving spoon in mug, locate strainer and pour tea, put strainer in sink, stir tea and put spoon in sink, poor milk into mug, replace milk in refrigerator (leaving tea-caddy and sugar-jar on work-surface). Take mug of tea away to be drunk.

3.3.2.2 We find what seems to be a sort of pseudo-random behaviour, perhaps constrained by the relative locations of cupboards, sink and refrigerator, and reflecting a casual attitude to replacing tea and sugar in their customary places. The components are interleaved (their sub-components are sequenced) and not always 'completed'. Further reflection on the task shows that the order in which milk and tea are added to the cup/mug is variable – there is no inherent sequence. However, their may be a cultural factor [GCP1: Cor2] whereby one sequence is preferred over another. For example, some people argue that adding hot tea to the milk in the cup prevents the milk scalding (adding the milk to the hot tea apparently scalds the milk, altering the flavour of the final cup of tea); in some cultures the tea-leaves are added to the boiling water in the kettle (which thereby becomes the tea-pot!).

3.4 Assembling behaviour

The laboriously worked illustration provided above reveals something important. The observable sequence of behaviours is the result of assembling sets of sequenced behaviours, perhaps with overall random or ritualized patterning, in sequential sets or in complex interleaved patterns. The two components of the second general principle can be recognized as underpinning the observable activity. The sequencing is possible because the atemporal but dual nature of the cognitive entities provides sequencibility, thus conforming to the sequential imperative, without specifying the exact sequences (as seen in section 2).

The final sequence is generated by the behaviour itself in the context of other contingent behaviour and circumstances, including custom and the prior state of the kitchen; the observed sequence is not simply the external version of a fully sequenced cognitive precursor, nor even of an atemporal but complete specification of the sequences. There is no need for either of these accounts to be assumed – rather, the behaviour unfolds as the process of sequencing the (sub-) components produces observable activity.

4 The Sequential Imperative – III

GCP3
Behaviour is sequencing; perception is de-sequencing.

The preceding sections provide an account of the two central principles. These can briefly be summarized as introducing the notion of the *sequential imperative* along with some implications. The implications are simply that sequentiality is forced on an organism physiologically and is therefore free to be given significance, and that because sequence penetrates the corporeal boundary it provides the means by which cognitive structures (atemporal and dual) can be externalized and internalized. But this latter activity is governed by GCP3, and thus the sequential imperative is actually a summary of the three principles, as we shall see.

These issues can now be examined in relation to a different domain of behaviour, namely human language. In this section we will briefly sketch a model of behaviour which is both general and linguistic. Whilst we will not address learning, it should become clear that anything which can be said about learning will apply equally to linguistic and other behaviours.

4.1 Segmentation

The first two principles are complementary in their coverage of the central problem in cognitive science – segmentation. This problem can be re-expressed in terms of two questions, one concerned with structure and the other with process: how does the organism attribute meaning to temporal segments?, how are the temporal segments located in the continuous stream of activity?.

It is not uncommon for discussions of possible answerings – in relation, say, to speech perception – to reach the point where it is decided that segmentation is dependent on recovery of meaning, but recovery of meaning is dependent on successful segmentation. This difficulty – sometimes rephrased in terms of resolving the question of whether 'top-down' processing is more important that 'bottom-up' (or vice versa) – is actually one of our own making.

The insights available through the first two principles show us that the problem of segmentation – as rephrased in the two questions just posed – is solved by recognizing *why* segmentation is necessary. Behaviour is linearized segmentally to provide a temporally organized expression of atemporal entities [GCP2]. Thus the 'problem of segmentation' is that of transforming structures into and out of the temporal domain. The answer is GCP3: Behaviour is sequencing; perception is de-sequencing.

4.1.1 *The two questions* posed earlier actually tease apart the atemporal domain – meaning – from the temporal domain – segment stream. However, the redescription of the questions in terms of 'top-down' and 'bottom-up' processing, which seems not unusual, does not

acknowledge the dimensional shift. Diagrammatically, the common misperception is of hierarchical structures, as illustrated in Figure 1.

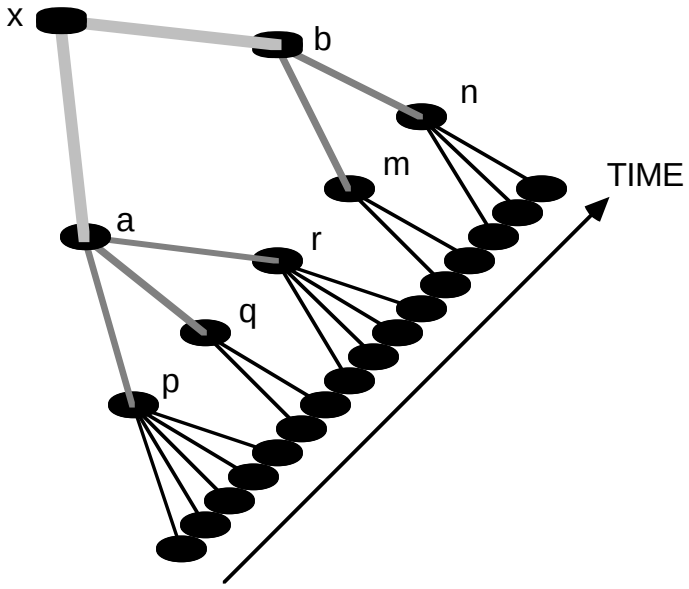

Figure 1

In contrast, the dimensional shift looks rather more like a Naum Gabo 'construction' with meaning not extended structurally in two dimensions one of which is the temporal domain, but in two dimensions neither of which is the temporal domain. This is shown in Figure 2.

4.1.2 *The use of three-dimensional illustrations* is not accidental. The discussion focuses on the exploitation of the time domain for linearizing entities which are not themselves arranged in time. Thus in Figure 1 it is a necessary property of the tree diagram that the nodes *p,q,r,m,n* are arranged in sequence, as are the nodes *a,b*. In contrast, in Figure 2, we see that the nodes are not in any sequential relationship, only the original line of segments is arranged in sequence, as in Figure 1. This style of illustration is also found, with some differences, in some "non-linear" phonological formalisms (from which this approach has evolved).

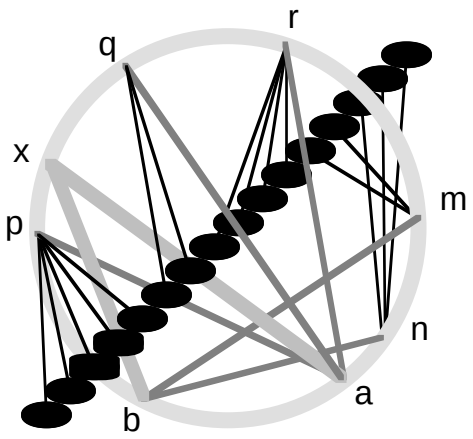

Figure 2

4.1.3 *The solution to the problem of segmentation* is sketched in the two illustrations above. Figure 1 illustrates the conventional hierarchical approach, with the implication of temporal organization of the cognitive precursors of the final 'output' stream of segments. Figure 2, in contrast, shows that the cognitive precursors – the nodes *a,b,m,n,p,q,r* – need not be arranged in time at all – they are co-present, or simultaneous.

4.2 Linguistic structures and segmentation

The structures compared in Figures 1 and 2 have an important property – there is no time-scale attached to the linear sequence of segments. It is also the case that none of the components is identified. These two diagrams can as readily represent the tea-making behaviour discussed above as they can represent syntactic structures in sentences, or phonological structures in words (or signs in a sign language, for that matter, cf. Edmondson 1996). In the most general reading of these structures the following points emerge. Segments are no longer fully isolated and specified; rather they are readings of fragments of time. Both behaviour and perception are concerned with characterization of these fragments of time – at all scales of description. Behaviour requires such characterization for the purpose of specifying actions – sequencing in 'output' the co-occurring precursors of behaviour. Perception requires such characterization for the de-sequencing of sensory 'input' and the recovery of the atemporal specifications. This pattern of sequencing and de-sequencing is readily appreciated in linguistic terms, just as Figure 2 is readily seen as representational of phonological structures.

4.2.1 *Linguistic structures are not special* – the structural account given above really is generally applicable regardless of modality of behaviour (for example, signed languages and spoken languages are equivalently represented) or the nature of the behaviour more loosely (for example, cooking a meal is as readily accounted for as the structure of classifier morphology in Swahili, cf. Edmondson 1990). Because sequence is semiotically free, and in many cases also arbitrary, languages have enormous freedom as to how they exploit segmentation and structures – compliant with psychological constraints (word order patterns are distributed asymmetrically amongst languages, for example), and without the need to postulate special linguistic constraints (such a need would follow demonstration of inadequacy in the general principles; not a belief they cannot exist).

5 Conclusions

The sequential imperative, as outlined above, encapsulates the first three general cognitive principles listed at the outset. Our purpose has been to establish that a case might be made that such principles can serve as the basis for a comprehensive explanation of cognitive activity, including linguistic activity. It can be seen that linguistic behaviour is probably indistinguishable from any other behaviour in terms of the essential structural motivations and

elements, and thus if any behaviour is learnable linguistic behaviour must be learnable in the same way. It is now plausible that comprehensive accounts of behaviour, its organization and its "acquisition", will show that linguistic behaviour does not require special treatment or mechanisms.

6 References

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