Chapter 1
Cognition and language acquisition: psycholinguistic artefacts or neural activation patterns?

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1.1 Introduction

The relationship between general cognitive development and language development partly due to the fact that the nature, conditions and processes that characterise general learning principles are also applicable to language, since language acquisition and comprehension are derivatives of non-linguistic skills, as Lieberman (1984) believes. Moreover, it is assumed for the purpose of this study that the processes and mechanisms of learning a language may be best understood with reference to a common neural architecture; one that undertakes varied functions in response to varied nature of inputs. The present chapter deals with the theoretical issues associated with language learning – theories of cognition, logical reasoning and construction of meaning, and we evaluate them in the light of current neurobiological findings and argue for the necessity of an integrated approach to understand language comprehension as a continuous process of identification, association, meaning extraction and expression. It thus provides the theoretical basis of the research carried out in the present thesis.

1.2 Cognition, Language and Conceptual structures

Comprehension of language is one of the specialised tasks performed by a neuronal architecture specialised in information processing by providing S-R associations and modulating higher mental functions. Chomsky calls the ability of understanding language performed along such lines as the competence of an ideal speaker-hearer, and his understanding of the human language faculty takes into account the cognitive nature of the human mind\(^1\) (Chomsky, 1965, 1986, 1991a). In considering the role and scope of the mind in the process of acquiring a language, Chomsky had proposed an abstract mental framework

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\(^1\) The brain is an organ, comprising of an aggregation of neurons that have a physical basis; whereas the mind is a construct for our convenience to give a structure to the way in which we think thought is organised. Mind is the collective functional state of the synchronised operation of the brain.
called **language acquisition device**, or **LAD**,\(^2\) which can be characterised by a set of formal, logical structures, principles and parameters believed to be innate in nature, inasmuch as the proposal theorizes that humans are predisposed via a genetic mechanism, or ‘bioprogram,’ to learn language (Chomsky, 1995).

Chomsky’s postulates about linguistic behaviour (sic!) is one of the major advances in linguistic thought, and his innateness argument is definitely ingenious. When it was first proposed (Chomsky, 1957), it created a completely new paradigm of formal, logic-based ontology of language structure, suitable for adaptation by computer scientists to form the basis of many language-based applications, such as grammatical parsers and machine translation tools. It marked a shift from earlier behaviouristic explanation of language ‘internalisation’, to a mentalist-cognitive framework, although later on subtle distinctions between the mentalist and cognitivist positions also started to emerge. The foremost thrust of this shift was to revise our conception of the characteristic nature of language learning: from conceptions of *language learning as behaviour formation via stimulus-response pattern and mechanical imitation* (cf. Skinner, 1957) to a more *cognitively-oriented active learning process that is self-actualising and constantly growing*.

1.2.1 **Chomsky’s formulation**

Chomsky’s (1976, 1984) conceptualisation of the linguistic processing as a ‘mental organ’ describes the acquisition of a language as internalisation of a system of rules that relate sounds and meaning in a particular way. This set of sound-meaning relationships is the mental reality behind actual linguistic behaviour, important for interpretation of sentences. This is possible, according to Chomsky (1984), because the interpretations are made possible through a process involving the capturing of principles via a set of syntactic, semantic and phonological rules, operationalised through underlying representations, **DS** or **deep structures** that reflect the innate linguistic capability of the mind. Opposed to these are the **surface structures** (**SS**), resulting out of the deep structures by undergoing certain ordered

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\(^2\) The short span of time within which language is acquired, led Chomsky to propose the ‘poverty-of-stimulus’ argument, thereby leading to speculations about the innate nature of the ‘language acquisition device’ (**LAD**) component of the human mind (Chomsky, 1965, 45-47). However, the exact nature of this genetic mechanism that is so fundamental to Chomsky’s theory has not been discussed in any substantial measure in any of his earlier writings. Only recently has his reconciliation with biological evidence begun (Hauser, Chomsky & Fitch, 2002). In any case, language cannot be programmed by genes; only processes that might lead to it.
and specific transformations. The goals of Chomskyan theory are to describe language as a property of the human mind and to explain its source. To achieve these ends, Chomsky's central argument is built around the concept of 'universal grammar' or UG that he had described earlier as 'the system of principles, conditions, and rules that are elements or properties of all human languages' (Chomsky, 1978, 29). Chomskyan theory reduces the language faculty to a complex overall formulation involving abstract sub-theories. UG is thus a theory of knowledge; it is concerned with how the cognitive structure of the human mind is organized and operates to facilitate language comprehension and production. The theory thus necessitates the separation of various compartments, the separate modules of the mind: UG describes only the language module. Chomsky (1976) states it thus,

The theory of language is simply that part of human psychology that is concerned with one particular "mental organ," human language.

(Chomsky, 1976, 36-37)

However, Chomsky does not state that the integration of the language faculty with other faculties as inconceivable, merely that the proposals, suggestions and evidences proffered for the evaluation of the integration proposal have remained largely inadequate and inconclusive (Cook, 1993, 20). It is noteworthy that language typologists have pointed out a grave shortcoming in Chomsky's claim about innateness, that in the light of the enormous variation in the linguistic systems, it is especially "problematic when viewed without an a priori commitment to Chomsky's paradigm" (Comrie, 1981, 24). In all fairness to Chomsky's position, he has never rejected the possibility of more concrete and physical basis for language, merely stating that particular psychological functioning responsible for language acquisition seem to be guided by innate principles (see Fig.1.1):

3 In the absence of more definitive evidence, Chomsky's idea of the language faculty being an autonomous faculty of the mind stands to reason. Chomsky maintains to this day that innateness is a possible explanation of linguistic function, and that linguists need look only at the logical organisation of the system, FLN, while leaving any other explanation of linguistic function to become the subject matter of FLB. In contrast, cognitive theories assume the mind to be an integrated entity: Anderson (1983) argues that structure dependency (treated as a principle in UG) is a function of some general cognitive property. As we shall see later, the brain can process language as a non-autonomous faculty, as a part of the general faculties of memory processes and intelligent problem-solving behaviour through resonances of neural ensembles.
Fig. 1.1 Schematic diagram of the structure of linguistic theory describing knowledge of language as an interlocking set of sub-theories consisting of principles and parameters (Chomsky, 1986a, 120ff) (after Cook, V.J., 1993).

1.2.2 The Modularity Hypothesis

The shift in the nature of the heuristics referred to above prompted theorists of language and education to engineer a concomitant shift in their stance about the nature of concept formation: from mechanical, structure-based, schema-driven operations to dynamic, factor-based, adaptive system. One consequence of this shift is seen in the conceptualisations of the theories of mind (ToM): from mind as 'fixed' artefact (Skinner, 1957) to mind as 'modular' entity (cf. Chomsky 1965, Fodor 1983, 1990). In fact, the most useful discussion of what is meant by 'modularity' is found in Fodor (1983): he approached the functional neural architecture of the mind as a number of properties to be fulfilled: domain-specificity, innateness, information encapsulation, rapidity, neuronal specificity or 'hardwiring', and autonomy. This approach to the problem of the nature of the mind is referred to as the computational theory of mind (cToM), and arises out of the notion that the mind is a composite of a variety of computational devices, each specialized to perform a particular way of dealing with information of a particular kind. Coltheart (2001) extends this notion of
modularity to include, within the functional architecture-dependent definition of ‘module,’ the information processing system identified by the neuronal pathways of information flow being functionally and anatomically distinct.

1.2.3 Fodor’s theory

Fodor’s theory of mental representation specifies a set of sufficient conditions for a mental state \( S_b \) to represent an object \( B \), as an instance of type-\( B \) objects that exist in reality (Fodor, 1990, 121-122). This is one version of the representational theory of mind (R'TM), in which mental systems are specified functionally. Any concept is formed initially by the transduction of properties (conversion of external stimuli into mental representations that approximate the stimuli). This is because, according to Fodor (1986), the human ability to selectively respond to nonnomic (not natural law-dictated) properties is what makes humans possess mental states,

\[ \text{...we [humans] are frequently implicated in primal scenes in which behaviourally efficacious stimulus property...is nonnomic....the difference between paramecia and us is that we can 'respond' effectively to nonnomic stimulus properties and they can't.} \]

(Fodor, 1986, 11)

He claims that a system must respond selectively to at least one nonnomic property to have a mind. However, this is like placing the cart before the horse. The point is that unless one has a mind, one cannot respond to nonnomic properties – the mind is a prerequisite to its response. But we do not till now know how a physical brain gives rise to a mental representation. Consequently, the systems-level behaviour of the neurons and its interconnections due to a learning process needs to be quantified and investigated for the existence of the ‘mind.’

1.3 Inconsistency of current theoretical views

Difficulties are encountered at several levels in testing the modularity hypothesis as applied to language. It contains no explicit reference to the topological properties and dynamics of neurons that are needed in order to explain network behaviour and do not comprise a model as defined in the Introduction. They provide no anatomical or physiological basis for predicting forms of trigger features from one hierarchical level to another beyond the already known speculative ones. Even if we consider the output from the distribution, it may or may not be sufficiently focused by recursive mechanisms into a smaller distribution.
Experimental testing of these implicit assertions will require use of techniques for studying mass actions, i.e., investigating network properties.

Further, the neural mechanisms for convergence of activity are unlikely to produce a phenomenon across multiple hierarchies as is the case with language, because it is likely that the cortex contains both excitatory and inhibitory neurons. Additionally, before a quantitative study of the spatial and temporal dynamics can be undertaken, the topological problem should be resolved. It appears feasible to construct mass action models in line with the visual cortex model evolved by Hubel & Wiesel (1962), and to test them physiologically as the means for solving this problem. But the explanations must subsume even more complex levels of analysis, since the interactions giving rise to the simple and complex response configurations of cortical neurons are global properties based on local connection densities within the human brain. These neural mechanisms should be clearly understood, before extrapolations are made to their operations on global cortical patterns or on sensory patterns involving multiple modalities, which is the norm in language comprehension/production.

1.3.1 The biological reality

Both the theories described above encounter a procedural roadblock when trying to explain how the systems-level interconnectivity of the physical brain might generate abstract representations such as those of linguistic categories and their acquisition, as was just discussed, without which such mental manipulation of speech is not possible since language is iconic, and ephemeral to add to it. While processing the information contained in linguistic items, the brain must do so at a very high speed to give shape to a resulting proposition in the form of a mental image that is capable of further manipulations, and also hold analogous information in both working memory (WM) for use in real-time processing of language, as well as in long-term memory (LTM) for future reference and retrieval. This issue is not at all raised in pre-Chomskyan linguistics, and Chomsky merely hints at its theoretical possibility (cf. 'trace' artefact) in his early writings – that there does exist such a logical mechanism, but given the state of knowledge about how memories function, it was not possible to attempt to find the neuronal correlates of such a characterisation, let alone try to study its ability to be manipulated. Chomsky's objection was because all proposals till that time had been rather inadequate in describing this connection, "since only the vaguest of suggestions have been offered, it is impossible, at present, to evaluate these proposals" (Chomsky, 1972c, 26).
However, brain science has since made enough progress to start attempting to answer this question as a fundamental problem of 'hard' neuroscience. This leads us to the examination of the functioning of the brain in processing language and its anatomical organisation and functional specificity. This is important because a direct investigation of the neural activity mediating the relation of the cognitive activity with its neuronal counterpart (as has been done in chapters 3 and 4), will be a critical step towards a mechanistic model of human language processing.4

A central tenet in evolutionary language research is to focus on how the "formal" criteria governing language could have "evolved from adapting existing structures in the ever-changing conditions of life" (Lieberman, 2000, 166). To this effect, Jenkins puts forth Chomsky's proposal of a 'mental organ'5 for language in the following manner:

The brain is not a homogeneous organ but consists of subcomponents or modules, each specialized for different purposes – vision, the number faculty, the language faculty, etc. (Jenkins, 2000, 58)

However, this is biologically untenable given that no such anatomical organ exists in the human brain. Further, existence of such an organ raises questions of localisation of the physical characteristics of language at all levels i.e. phonetic, phonological, lexical, morphological, syntactic and discoursal, in the brain. The individual differences observed in the expression and perception of linguistic characters therefore require the process of cognition to be known. Recent evidence however, suggests that cognition is distributed in large, interconnected anatomical networks throughout the brain (Goldman-Rakic, 1988).

These evidences suggest existence of higher order network connectivity among different populations of neurons in so-called 'modular' brain. Hence, the basic tenet of cognitive neuropsychology that the human mind is organised on modular principles (Fodor, 1983) is itself under attack after a host of evidence collected in favour of more distributed networks:

(i) Cognitive activity such as retrieval of single words activates widespread regions (Wise et al., 1991).

4 This will help in suggesting ways to enhance language curricula through targeted biobehavioural interventions. 5 See also Andedson and Lightfoot (2000), who claim language to be mediated by an organ in the human mind/brain, and treats language as an epiphenomena, derivative of many people's individual grammars, but treats grammars as a formal, finite system of an individual's linguistic capacity.
(ii) First and second languages share cortical systems across hemispheres (Illes, et al., 1999; Perani et al., 2003).

(iii) Implication of the ventral visual pathway in auditory processing (Büchel, Price, & Friston, 1998) and that processing of words through visual channel is also accessible through auditorily acquired channels very early in the processing stream (Petersen et al., 1988) – This means that information processing in the brain is essentially multimodal and distributed over various networks.


1.3.2 Plasticity takes on modularity

One major assumption that Chomsky has made is the modularity of the mind: “I am tentatively assuming the mind to be modular in structure, a system of interacting subsystems that have their own special properties” (Chomsky, 1980, 89). He goes on to delineate his proposal on the basis of this assumption. However, questions regarding the validity of this argument remain. There seems to be no compelling reason in Chomsky’s argument other than the logico-deductive theorising that depends on such unverifiable scenarios and hypothetical UG to account for a biological phenomenon such as language; whereas research should be directed towards discovering and describing the biological processes subserving language, and processes are mediated by network operations that cover several areas of the brain simultaneously. In addition, apart from the widespread cortical activations reported for cognitive tasks, recent evidence collected by neurophysiologists also suggest that the essential characteristic of the brain is that it is ‘plastic,’ i.e., structured in terms of specific neural connections that are not fixed but change over time. The cortex is malleable in a way that specialised functions of specific regions are not fixed but are shaped by experience and learning. In non-human primates, for example, the brain systems interact together as a whole with the external world (Elman et al., 1997, 340). The brain is ‘hardwired,’ or has dedicated cortical connections; but the exceptional processing prowess of the brain is also supported by

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6 As adjacent neurons become connected to form circuits, connections also begin to develop with neurons in other regions of the brain associated with other relevant sensory information to give meaning to the acoustic signal (word) associated with the concept. This is what gives meaning to the word, along with related lexical and thematic or lemma information.
neuronal flexibility of the developing brain (Elman et al., 1997; Karni et al., 1995). This fact has profound implications for learning, as it suggests that the neural basis for learning resides in connections between neurons: neurochemical signal transduction between neurons that is facilitated by dynamic balance of metabotropic inputs cause neurons to switch functional states and give rise to learning behaviour (Derjean et al., 2003). Neuronal network oscillations at distinct frequencies have also been implicated in encoding, consolidation and retrieval of information in the hippocampus (Klausberger et al., 2003). In addition, evidence from brain lesion and lateralisation studies suggest that the organisation of information flow in these specific areas of the brain that are implicated in specific learning domains can change over the life span. Moreover, higher order brain centres (such as the frontal and temporal lobes) that process complex, abstract information can activate and interact with lower order centres and vice versa (Murphy, 2002, 2003). This ability of the brain makes us realise that the interaction of sensory and cognitive processes lead to the solution of the ‘stability-plasticity’ dilemma (Grossberg & Merrill, 1996), and helps us rapidly learn about the world and stabilise its representation throughout our lives, without catastrophically forgetting our previous experience, i.e., our brains remain plastic and open to new neuronal connections, while at the same time the stability of previous memories and learning are not compromised, except when the relevant connections fall into disuse, or are damaged by accidental lesions or disease, thereby inducing cortical map plasticity by long-term depression (LTD). Therefore, participation of sensory and cognitive matching involved in learning, being excitatory, leads to resonance attractor states in the relevant neuronal networks. Such resonance states have been implicated in sequential processing in identified brain circuits (Grossberg, 2000a), and recently in UP-state attractor dynamics (Klausberger et al., 2003).

7 Studies done on rodents support the view that transplanted cortical tissue from visual cortex transplanted to regions normally ascribed to sensorimotor functions, take up the functions of the sensorimotor area (O’Leary & Stanfield, 1985); also when transplanted sensory input from the optic nerve is redirected to the auditory cortex, the auditory cortex processes visual, and not auditory input (Sur, Pallas, & Roe, 1990). These studies support that it is the nature of input that determines the function of the specific cortical areas; the neuronal tissue merely responds to it.

8 The hippocampus is implicated in reactivation of long-term memory systems (Nader, 2003).
1.4 Redefining concepts in an integrative framework

1.4.1 The active process of making meaning: learning as establishment of cognitive templates rich in information

All human beings possess the ability to categorise and organise information, which they use to interpret the world. New information is processed according to how it fits into these rules of behaviour. The dynamicity of behaviour can be used not only to interpret but also to predict situations occurring in our environment. Information that does not fit into this general order may not be comprehended correctly, or may not be comprehended at all. This is the reason why a person may have a difficult time comprehending a text on a subject he is not familiar with, even if he comprehends the meaning of the individual words in the passage. It may be an even more difficult task if the structural-functional relationship between the lexical items is not accessible to the framework of the learner’s information processing capacities.

The cognitive nature of knowledge structures represents a kind of mental template. Such templates are stored in long term memory (LTM) and are invoked when we interpret our experiences, providing general outlines of the features of phenomena usually associated with familiar situations: typicality, preconditions, information roles, motives and results (effects). Many psychological experiments have shown the importance of our expectations in making sense of new experiences (Richeson et al., 2003). These mental templates mediate the perception, comprehension, interpretation and recall, all of which are typical of human information processing. Interpreting events or relationships involves mapping the available information onto an appropriate template, already stored in memory.

We derive these templates from our past experience, as memory ‘traces,’ which can be diagrammed as hierarchical networks of concept nodes and concept links. Some commentators refer to a ‘frame.’ A formally elaborated representation of how templates seem to work is shown in Fig.1.2. A template is activated when a feature in a situation appears to match part of the information represented in the available neural network. This activation involves ‘features’ in the information being ‘identified’ where they do exist as memory traces – explicit features of the specific situation, or ‘default values’ where some features are not explicit. Where particular features are not explicit, the template offers those which one would normally expect in such circumstances (filling up the slots by inference and interpolation). The brain must process the information statistically to generate such patterns (expectations).
Neurobiological evidence of such template matching and slot-filling comes from experiments on learning and memory (see Chapter 3 for a detailed discussion on this issue).

Figure 1.2: Flow chart representing the operation of templates. Events occur on the left and recall is represented on the right. In between, inferences are made and stored in memory (modified and adapted from Deaux & Wrightsman, 1988, 22)

Comprehension can be regarded as selecting such templates by pattern matching and confirming that they are appropriate for the context being interpreted, or (when necessary) constructing a new template that works. A person who cannot find a template that seems to fit may find the incoming information totally incomprehensible, although this is certainly not to suggest that only one interpretation of an incoming sound stream is ever possible. However, such entities as lexical items have more or less fixed interpretations that evoke almost similar patterns in every normal human being. Memory is based on the same structures as comprehension. What is recalled is not the actual words but a reconstruction based on what the person understood by his/her share of experience of incoming stimuli. As time passes we are increasingly less likely to be able to distinguish between details in the acoustic signature of what the lexical item generated and rely more on the impression it created neurally by applying the template available to us.

Six key functions have been proposed for such templates:

i. As ‘ideational scaffolding’ for assimilating new information. Information that fits the slots in one’s mental template is easily learned, perhaps with less effort.
ii. For facilitating selective allocation of attention. They help to determine the important parts of contextual information, and guide the person regarding where to pay close attention.

iii. To assist inferential elaboration. To allow one to go beyond the information which is explicit in an information stream.

iv. To allow orderly searches of memory. Acting as a guide to the types of information that need to be recalled.

v. To facilitate editing and summarizing (since it includes a key to items of importance).

vi. To permit inferential reconstruction where there are gaps in recalled information.

(see Anderson in Singer & Ruddell, 1985, 376-377)

Ausubel (1968) postulated a hierarchical organisation of knowledge where the learner more or less attached new knowledge to the existing hierarchy. In this representation, memory is driven by structure as well as meaning. In contrast to Ausubel's Meaningful Receptive Learning Theory, the modern theories posit that the learner actively constructs templates and revises them in the light of new information. Each individual's schematic representation of the information matrix is unique and dependent on that individual's experiences and cognitive processes. Knowledge, however, is not necessarily stored hierarchically. In fact, it is meaning-driven and probably represented propositionally, and the learner actively constructs these networks of propositions, e.g., when we are asked to recall a story that we were told, we are able to reconstruct the meaning of the story, but usually not the exact sentences – or even often the exact order – that we are told. We remember the story by actively constructing a meaningful representation of the story from our memory.

Mental templates are important not just in interpreting such information, but also in decoding how that information is presented. This kind of schematic organisation of information can be reflected in textual structures, for example, readers use their schematic representations of text (narrative, compare/contrast, cause/effect, etc.) to help them interpret the information in the text (Driscoll, 1997; Halliday & Hasan, 1989). The template reflecting how information is presented can also be culturally determined – it is language that plays this role. Specifically, language casts the template in terms of the information structure that can be gleaned from the structural-functional information carried by the linguistic items. Language is a set of psychologically oriented artefacts that interact to give meaning to our conception of
the world and is culturally learnt; hence, it is the structural-functional template of language built that triggers the functional dynamics of language.  

In addition to such templates, learners are also thought to have mental models, which are dynamic models for problem solving based on a learner's existing schematic organisation of knowledge and perceptions of task demand and task performance. According to Driscoll (1994) “what this means is that people bring to tasks imprecise, partial, and idiosyncratic understandings that evolve with experience” (Driscoll, 1994, 152).

1.4.2 The psychological reality of concepts

One key definition of concept that has emerged recently is that by Barsalou (1999). According to him, the primary sensory inputs generate the primary or concrete concepts, and higher-level concepts are composed further from them, eventually leading to complex, abstract representations. The fundamental assumption made by him is that cognition is inherently perceptual and perceptual states arise in sensori-motor systems. As Barsalou (1999) states,

A perceptual state can contain two components: an unconscious neural10 representation of physical input, and an optional conscious experience. Once a perceptual state arises, a subset of it is extracted via selective attention and stored permanently in long-term memory. On later retrievals, this perceptual memory can function symbolically, standing for referents in the world, and entering into symbol manipulation. As collections of perceptual symbols develop, they constitute the representations that underlie cognition.

(Barsalou, 1999, 577-588)

This psychological reality experienced by us is only indirectly related to the physical attributes and their sensory correlates: the world is thus cognised through a ‘conceptual/categorical filter’ (Ausubel 1968, 505). This filter operates through the creation of a feature11 repertoire (for categorisation and object12 recognition), dependent on situational demands (Schyns, Goldstone & Thibaut, 1998), or in neurophysiological terms, through temporally encoded spike pulses (Cariani, 2004). As features are identified by their functional

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9 See for example, Kaplan (1966), who stated that the structure of formal argumentative essays is culturally determined and therefore second language writers and readers must not only have sufficient command of their second language but also of the textual structures in their second language.

10 For the purpose of this thesis, ‘neural’ here must be read as ‘neuronal’.

11 We define a feature as any elemental property (physical or abstract) of a distal stimulus that is an element in cognition of that object, i.e., a feature is the unit of psychological processing.
role in cognition rather than by their properties, the stimulus dimensions relevant for concept
creation are ordered sets of feature values that primarily depend on the loci and functional
roles of the properties in the whole scheme of hierarchical cognitive structure: ‘geons’ in the
recognition by components (RBC) theory for physical objects (Biederman, 1987); acoustic
signals in phoneme recognition (e.g. Jakobson, Fant, & Halle 1963; Chomsky & Halle, 1968;
Coleman, 1998) and semantic primitives like PTRANS and INGEST (Katz & Fodor, 1963).
The assumption, not necessarily true, in all these proposals is that the set of features described
is constant, which necessarily leads to a structured hierarchical representation of reality, which
however is not a faithful reconstruction of the process of feature encoding.

Memory-based ‘template’ theories, the notional framework of which has been
discussed in the previous section, are better equipped to deal with the process of feature
encoding, with their emphasis on concept formation occurring through the generation of
templates, which are in turn created by feature combination and rule ordering of systematic
relations (Fodor & Pylyshyn, 1988; Ullman, 1989). The changes in the information
requirements for encoding implicit information during higher order concept learning
(including academic propositional structures) can be handled only by a high-speed real-time
processing of meaning chunks, the constituent parts of which have to be recalled from
memory. Since learning and abstraction of knowledge systems is a set of periodic learning
phases (Long, 1990; Thompson, 1991), the learner can be ‘scaffolded’ through learning the
abstract systems by efficient pedagogy to promote cognitive development of the desired level.
Any learning is however strongly dependent on the motivation and reinforcement provided for
the world of interpretations of the learning stimulus made available by the environment.
Investigations into the nature of problem solving indicate that for effective resolution,
problems need to be defined and structured to allow (a) conceptualisation of the problem; and
(b) relationship to be established between the key knowledge domains (Danks, 1997;
Fauconnier & Turner, 1998; Franks, 1995; Hampton, 1987; Oberbeck et al., 2003).

Nevertheless, a broad symmetrical array exists in the conceptualisation patterns
demonstrated by the learners. The general understanding until recently has been the

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12 Objects include all types of objects, including linguistic objects.
13 Language, the most widely available representational system, is used for the purpose. It is efficient, robust and
optimised for maximal biological conservation, propagation, replicability and cultural transmission over
generations, and is powerful and creative enough to encode the almost infinite novel situations.
recognition of two forms of knowledge viz., procedural knowledge and conceptual knowledge. Theories involving both these forms of understanding primarily focus on the genesis of a particular type of knowledge in a given domain. The 'concepts-first' theories propose that the children initially develop (or are born with) conceptual knowledge in a domain and then use this conceptual knowledge to generate and select procedures for solving problems in that domain. Alternatively, the 'procedures-first' theories reiterate that concepts develop after procedural knowledge. The \textit{iterative model} (Rittle-Johnson, Seigler, & Alibali, 2001) for development of conceptual and procedural knowledge apparently resolves this controversy and states that either of them may start to develop first, depending on the relative timing and frequency of exposure to concepts and procedures in a domain. Evidence for this comes from the fact that the nature of conceptualisation is different among different persons, lending credence to the theory of individual differences (Gray, Chabris, & Braver, 2003).

Another dimension to our conception about how the process of understanding works, came with the advent of the \textit{procept} theory (Tall, 2000) in which 'procepts' bridge the gap between conceptual and procedural knowledge by the use of symbols that acts as a process as well as a concept. Tall’s theory does not preempt any procedural understanding independent of the understanding of the process concept. However, seen from the perspective of learning mathematical concepts, the procept theory and the iterative model share some common aspects: (a) the recognition of concepts as a set of related facts networked by symbolic logic with respect to the problem to be studied; (b) the stressed significance of procedures (or, in broader terms, processes) in perfecting conceptual skills; (c) the achievement of natural equilibrium in conceptual reasoning through an equilibrated proceptual and procedural learning. Both theories strongly indicate the development/evolution of the mind in terms of 'modularity,' as posited to be the case with language learning, a logical system akin to the mathematical system (see Chomsky, 1972 for an analogy in the linguistic domain). This principle of modularity projects an almost perfect picture of the development of a cognitive system where dedicated modules function in a given way; but seen from a pedagogical viewpoint, it underplays the role of the pedagogical language (given the multimodal nature of the input information stream). We hypothesise here that the functioning of any stable system such as the one that is involved in the formation of language competence is motivated by the environmental stimuli, i.e., the language of concept acquisition, which is most notably driven by the lexical semantic information matrix (Gijsel, Van Bon, & Bosman, 2004). Hence, in a
multilingual environment, the language of pedagogical discourse plays a major role in establishing as well as maintaining the links between the different nodes of the conceptual structure that is developing in the mind of the learner, and these must be accessible through memory mechanisms. The neuronal correlates of concept association will be investigated in Chapter 3. Further, the input linguistic data that provides the functional substratum to generate the notion about the structural necessities of the linguistic code, which in turn is responsible for the operationalisation and extension of the developing conceptual schema abstracted from memory, and then after suitable modification is returned back to the cortical labile state, is the subject of examination in Chapter 3.

The conceptual structure/schema/template is based on three fundamental attributes: icon, sound and meaning. Symbol is an associate of icon. The procedural and conceptual knowledge therefore become the process and attain an equilibrional state, respectively, between icon, sound and meaning. Language plays a major role in determining the nature of sound-meaning relationships and their interpretation. Inherent in this form of mental information structure, is that the brain is an information-processing automaton, and the ToM that it describes revolves around a crucial question: 'What kind of information is processed in the brain and how?' That is, what are the categories, distinctions, relations and constraints that must be encoded by the brain in order to account for the reality around us? In such an information-theoretic conception of the ToM, the questions to be addressed first relate to (a) constraints regarding the form of mental information that needs to be encoded in order to facilitate its storage and retrieval in real time, (b) the constraints on the nature of information that is to be processed, and (c) computational constraint on the nature of processing. These three components of the ToM may be compared to icon, sound and meaning, respectively. Information that is to be processed is significant in terms of the space of possibilities or available states. These state spaces have an inherent organisation in terms of independent degrees of freedom, each with a range of possibilities, either discrete (binary or n-ary) or continuous (analog). As Jackendoff (1993) puts it,

...this space can be thought of as the [computational] device’s space of hypotheses about how many different ways the world can be. An input received by the device may enable it to choose a location or region in the space of possible states. Thus a stimulus serves as information for the device...insofar as it drives the device into a particular state. This state, regarded against the background of the organisation of the total space of states constitutes the device’s representation of the stimulus: for the device, this state encodes how the world is in context of all the ways it might possibly be.

(Jackendoff, 1993. 2)
And again,

...an organized combinatorial space of distinctions [is] available to the brain. When we...use symbols to state a theory of mental representations, it is not the symbols themselves that are significant, but rather the distinctions possible in the system of symbols we use: these are...homologous to the organisation of the relevant subsystems of brain states.

(Jackendoff. 1993, 3)

Jackendoff goes on to describe a set of boundary conditions that arise at each step of information exchange between the various hierarchical components of the mind (see Figure 1.2) that characterise the constraints on the forms of mental information during language comprehension:

- Information enters the mind in various different sensory forms.
- Information leaves the mind as patterns of electrical stimulations to muscles (including muscles to organs for vocalisation) and glands.
- These input-output patterns must be encoded in a modality-independent central format.
- Since these information forms interact, the mind must have means for translating and transforming information to and from the central format, so as to understand the world around and also act upon it according to the situational demands.

(Jackendoff, 1993, 3)

These basic boundary conditions generate questions about the overall organisation of the mind and the role of information in trying to understand the representation of the reality around us. The representation of the reality is achieved by the mind in the following way:

![Diagram](image-url)

Figure 1.3: Forms of linguistic information and the representation of reality (after Jackendoff, 1993)

The above figure shows that the language 'faculty' (inside the box) interacts with the psychological representations at various steps and at numerous levels; and that this is possible if the feature set(s) that is/are extracted for the representation of reality at every step is
dynamic enough to incorporate/learn new features to meet the contingency. The same may be seen as an example of what Grossberg (2000) calls 'self-organising features.' Concepts are thus seen as a function of categorisation of conceptual states generated by a history of constantly adapting conceptual structures. A schema is thus an instantaneous representation of a concept.

What Jackendoff has probably missed, however, is the fact that the 'mind' is an abstraction, constructed for our convenience to visualise the operational mode of the brain. We no longer need to stick to the notion that mind/brain are analogous; rather we can, with the current state of knowledge in biological sciences, posit hypotheses about our cognitive functions through systems-level and spike train analysis of brain functions, study the brain's quantitative and characteristic patterns of electrophysiological responses, and explore the molecular mechanisms of many of the essential modes of cognitive activities. This leads us to the explanation of language as a functional property of a certain cytoarchitectonic organisation of the brain and its concomitant neural processing that operates at various platforms to process the variable complexity of information.

1.5 The structure of concepts

1.5.1 Hierarchical layers

Much of the current understanding regarding the nature of conceptual structures and the nature of learning is the result of the assumptions that (a) "the nature of the change called learning must in some fundamental sense [is] the same, regardless of what is being learnt" (Ausubel, 1968, 21) and (b) who learns it and for what purpose (Gagné, 1967, 296). However, the tendency of clubbing together the varying degrees of performance or capabilities of the learner is questionable and can also be quite confusing (cf. ibid., 297). In a teaching-learning situation such as a classroom, it is important to distinguish between such factors that characterise the internal and external conditions of effective learning for the kind of change in capability they imply. Of fundamental importance are the specifications of what engenders conceptual structures, what its characteristics are, and what the processes and mechanisms of the concept acquisition/formation are.

The definition of a concept is itself so variable that it is important to discuss the various definitions to get a feel of the magnitude and extent of their semantic ranges. The classical position on the definition of concepts is that they are representations of
communicative experiences in terms of essential (criterial, identifying) attributes about which people are differentially aware (Ausubel 1968, 505-506). Because of the influence of concepts within our cognitive structures, we experience highly schematic, selective and generalized representation of reality. The earlier reference to nonnomic processes (Fodor, 1986), the response to which leads to representation of the perceived reality in the mind, is a case in point. This characteristic representation of the reality around is what is achieved by the mental reference frame as a conceptual-intentional projection of this reference frame in terms of relational mappings and interconnections of primary sensory inputs and their articulatory-perceptual performance systems (in the particular case of language) (see HCF, 2002). The success of this correspondence of the mental and physical worlds is therefore determined by the efficiency of the relationships and interconnections that are activated (and must be achieved both neuronally as well as computationally; hence the importance of the neural ensembles and their dynamic operation is highlighted). The principle of economy must drive the computations at both these interface levels, a theme that has been incorporated in the Minimalist argument (Chomsky 1991a, 1991b, 1993). There are two important consequences of this experience: (1) the generic constructs and propositional combinations in relation to which the new correlative and derivative meanings are acquired and retained, and are activated as part of an organized body of knowledge; and (2) the manipulation, interrelation and reorganisation of ideas involved generate the ability of meaningful problem solving.

Finally, the grouping of concepts into potentially meaningful abstract mental manipulations makes possible the acquisition of abstract ideas by a referential activity that relates the perceived reality with the generated mental framework/structure. As Ausubel (1968) emphasises,

...concepts obviously represent only one [selectively schematised] of the many possible ways of defining a class, and enjoy no actual existence in the physical world. Psychologically speaking, however, concepts are real in the sense that: (a) they can be acquired, perceived, understood, and manipulated as if they enjoyed an independent existence of their own, and (b) they are perceived and understood, both denotatively, and in terms of their syntactic functions. (Author's italics)

(Ausubel, 1968, 507-508)
This psychologically real abstraction\(^\text{14}\), which can now be called a ‘concept’, constitutes reliably identifiable perceptual and cognisable conceptual entities about which there is consensus judgement about its semanticity. We thus see that concepts are psychological representations of how we perceive the world around us. They are used primarily for organising cognitive functioning in humans in terms of three basic functions: a representation function, a classification (or referring) function and a possible linguistic function (see Franks, 1995 for details). It is important at this stage to reiterate that language is iconic and hence necessarily built in terms of conceptual objects, from representations of sound-images (phonetic-phonemic) to morphemic to structural to discourse patterns. Hence, it is the goal of linguistic theory to arrive at an understanding of how the physical representation of real-time speech (in terms of its acoustic and energy signature) is encoded mentally for linguistic concepts to form. Hence, an analysis of the underlying neuronal representation(s) is a prerequisite for constructing any plausible theory of language.

It is generally believed that knowledge of the manner in which concepts combine to form complexes of concepts (or even higher level(s) of representation(s)) can provide us with an understanding of what conceptual structures may look like (e.g., Franks, 1995; Medin & Shoben, 1988; Smith, Osherson, Rips, & Keane, 1988). It has been suggested elsewhere (Cooper & Franks, 2000) that knowledge about the linguistic function can throw light on the constraints that exist in the process of concept combination. Hence, accounts of concepts in general terms are ascertained by evaluating critical factors concerning linguistic function. In addition, the classification function is parasitic on the representation function, and the linguistic function on classification function. Therefore, it may be deduced that in the hierarchical framework of cognitive structures that are modelled on conceptual states, the following hierarchy exists in the organisation of conceptual systems:

\(^{14}\) Each person has a different psychological experience; hence, there will be as many psychological versions of the same reality as there are persons. Moreover, every person’s version of the same reality may change over time as a result of additional experience. We can see an excellent example of how the same concept can have multiple versions among various people and over time in the discussion of the nature of light by physicists over centuries (for details see Kuhn, 1970).
1.5.2 Acquisition of meanings, conceptual structures and language learning

Human beings have a genetically determined potentiality for representational learning (Carstairs-McCarthy, 1999; Hurford, Studdert-Kennedy, & Knight, 1998): whether activated for concept learning (Ausubel 1968:47) or language learning (Anderson & Lightfoot, 2000; Chomsky, 1957, 1965, 1989, 1991; Cook, 1994). Language is arguably the most sophisticated of the representational forms that are available: All these representational learnings are made possible through memory traces (Chomsky, 1986; but see also Nader, 2003) that represent, and thereby signify, and map entirely unrelated patterns of vocal stimulation onto particular sound-meaning associations, and thereby to a reality that exists in real/imagined life. This is achieved, by dynamic reconsolidation of labile STM states into later, consolidated LTM structures cyclically achieved (Nader, 2003). Of particular interest is how such representational learning for separate individuals is shared among individuals belonging to a 'speech community', who share the norms of such a code, and how the shared meanings give rise to a language (internalised 'I-language' giving rise to 'E-language' or 'primary linguistic data' (PLD), or shared sets of meaning in individual instances or 'parole,' giving rise to a notion of a shared linguistic code or 'langue'). This potential for I-language representation

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Figure 1.4: Hierarchy of concept generation and combination

Representation

contents over which thought and inference about the world takes place

Classical Reference

contents employed in determining the classification/membership of a concept/idea or whether it is denoted or not

Linguistic processes

contents accessed in understanding language and concatenated according to linguistically appropriate rules to comprise a mental representation of the meanings of utterances

Concept combination
generating E-language specification necessitates a crucial potentiality for the linguistic code: that of actualising the potential representation as \( M_w \), which occurs typically by the end of the first year of a person's life (Deacon, 1997). Once this 'insight' (that representation of the world/thoughts is possible with sound-meaning associations and combinations) is firmly established in cognitive structure, it lays the necessary foundation for all subsequent representational learning...Later on, words begin to represent concepts and generic ideas, they become concept names and are equated in meaning with more and more abstract, generalized and 'categorical cognitive content.

(Ausubel, 1968, 48)

The criticial attributes for such representations are available from contexts expressed in already meaningful schemata/words. These criticial attributes must be meaningfully related (in the ToM) to conceptual structure before concept meanings emerge, since access to meaningful retrieval from memory associations is possible only when representational learning follows concept learning.

1.5.3 Conditions of learning meaning

Emergence of new meanings (usually as a concept generation through concept combination) is a derivative of how the learner reflects on the perceived reality that the information reflects, information that is carried by the ensemble of linguistic signs. According to Ausubel (1968), symbolically expressed ideas, as in language, are related in a non-arbitrary and substantive fashion to what the learner already knows, viz., to some relevant aspect of his knowledge structure, be it a word, concept, symbol or proposition. This means that two necessary conditions are met: firstly, that the learner has a meaningful learning set available that can relate the new material to his extant cognitive structure; and secondly, that the new material is potentially useful to him, and related non-arbitrarily and substantively to his previously acquired cognitive structure.

The twin factors affecting concept formation, logical meaningfulness and potential meaningfulness, represent the determining factors of the learner's cognitive structure. The availability and other properties of relevant content in differential cognitive structures (cf. Vygotsky's ZPD, see Nunan, 1992) in various learners is the most crucial factor determining potential meaningfulness of the two criteria described above – the first one, i.e., non-arbitrary relatability corresponds to a non-arbitrary relationship between ideas that lead to language; the second, and more the important criterion of substantive relatability implies that if the
linguistic material is sufficiently non-arbitrary, an ideationally equivalent symbol or group of symbols could be related to cognitive structure without any resultant change in meaning, i.e., the same concept could be expressed in synonymous codes and would convey potentially the same meaning.

Potential meaning ($M_{\text{potential}}$) inherent in certain symbolic expressions/propositions comes from representational learning of a given pattern of stimulation (as in vocal sounds) leads to actual/phenomenological (or psychological) meaning ($M_{\psi}$) as a product of a meaningful learning process. Meaningful learning results when $M_{\text{potential}}$ is converted into $M_{\psi}$. In other words, psychological meaning is the result when potential meaning converts into new, differentiated idiosyncratic cognitive content in an individual, as a result of non-arbitrarily and substantively being related to, and interacting with, relevant ideas already present in the learner’s cognitive structure. Psychological meaning is thus said to have been achieved, when potential meaning changes are registered as a function over time. The formalism may be captured by the following equation:

$$M_{\psi} = f(M_{\text{potential}}) \mid M_{\text{potential}} \rightarrow M'_{\text{potential}}$$

(1)

The change in $M_{\text{potential}}$ takes place according to the following relationship:

$$M_{\text{potential}} + \frac{d}{dt}(M_{\text{potential}}) = M'_{\text{potential}}$$

(2)

The change in $M_{\psi}$ occurs due to a continuous inflow of new information in a carrier wave (as acoustic signal, i.e., speech or as photonic signal, i.e., visual signal). It must be stressed here that meaningful learning and learning of potentially meaningful material are not the same: potentially meaningful material may already be meaningful in parts, but not as a whole. It is when treated as a unified concept, that meaningful learning takes place, by manifesting in the learner, a meaningful learning set that must be activated, in the cognitive structure of the learner. Thus, related words or vocal symbols will be non-arbitrarily and substantively related to the conceptual structure/schema/previous knowledge already extant in the learner’s mind, through the evocation of associations. Hence, cognition results in better understanding when conceptual structures are activated and flux generated in $M_{\psi}$, by a word/symbol/signal/proposition, with greater associativity with previously learnt words/symbols/schemata/propositions.
1.5.4 The acquisition of linguistic competence: syntax

The linguistic function of syntax is to posit a set of rules for combining words and inflections into meaningful propositions. Its psychological function, however, goes much beyond that: rules of syntax primarily serve the *transactional* function of bringing *speech* (acoustically expressed meaning carriers) and *ideas* (images and concepts) into a synergistic relationship by activating psychological mechanisms in a reliable and non-arbitrary fashion and generate and understand new ideas. A given group of temporally sequenced sounds, then, carries not only grammatical information about the words formed out of the concatenations that make up the sequence, but also the speaker’s intention. Therefore, both distinctive *denotative meaning* and additional *semantic information* (through syntactic functions) contribute towards understanding a proposition. In fact, the latter must precede the former, to allow $M_v$ to crystallize out of the whole process of ascertaining the relationship between sound and meaning.

The principal psychological problems with respect to grammar, then, are to specify the cognitive processes involved in generating and understanding sentences.

(Ausubel, 1968, 67-68)

Nader’s formulation of a dynamic state-dependent conceptual structural framework for memory representations by cyclic ordering and alternation in activation states in differential brain regions, is thus an important piece of evidence in support of a cognitive approach to language learning.

1.5.5 Entity-event space, cognitive grammar and the origins of language

The working of the cognitive component of the mind remains a mystery, although we are slowly comprehending some basic functions. Attempts to understand its mode of functioning has resulted in theories known variously as *cognitive grammar* (Langacker, 1987) or Adaptive Control of Thought (or ACT) theory (Anderson, 1983). The current understanding in most of the recent research is that acquisition and retention of large amounts of meaning are encoded in a systematic manner in a systematic *schematic* formulation. *Dynamic functioning* of this schematic formulation usually starts after initial ‘concrete’ learning, mediated through language. In the process of charting the underlying structures and mechanisms of the human brain that makes language possible, Bickerton (1990), Jackendoff (1997) and earlier Lenneberg (1967) shared the belief that language is not so much as a
system of communication (on which social selection pressures might indeed have come to bear), as it is a system for mental representation and thought. Lenneberg's (1967) seminal work represented language as a self-contained biological system, with perceptual, motor and cognitive (neural?) modes; he therefore saw language and cognition (understood in terms of mental representation of the world around, i.e., reality) as two complementary abstractions. In trying to fathom the relationship between language and its representation in the brain, some scientists have invariably focussed attention on the evolution of linguistic form and its role in human evolution. Bickerton (1990) has stressed that instead of communication as the manifestation of language, we ought to look at it as a basic system of representation of reality. He asserts quite forcefully that natural selection would seem to favour increasingly complex systems of perceiving and representing the world, as it would accord an organism better chance of survival, and further gain in knowledge about the world (cognition) would come from a concomitant complexity of representations involving language. This would mean that vocal signals, which arguably is the most economical method of communication that ensures reception over a considerable spatiotemporal expanse, would eventually lead to 'protolanguage', a system of arbitrary reference which is 'a system of representation, a means of sorting and manipulating the plethora of information' by 'some kind of label to be attached to a small number of preexisting concepts' (Bickerton, 1990, 5, 127-128). Language as a biological adaptation for evolutionary advantage has thus gained a substantial following among the scientific world (Pinker & Bloom, 1990; Nowak, Komarova & Niyogi 2001), and it clearly presumes that language would be a factor of evolutionary change only if it is considered as something that offered advantage in the 'information game' (Hurford, Studdert-Kennedy, & Knight, 1998).

Many recent studies have attested this kind of a genetically based cognitive leap that provided the link between cognition and communication. Pinker and Bloom (1990), in particular, have emphasised that this evolutionary leap provided early hominids with 'an obvious advantage to being able to acquire information second-hand' by avoiding duplication of time-consuming trial-and-error process (p.712). The leap that we are talking about was arguably the result of two simultaneous events: firstly, neocortical expansion in *Homo sapiens* about 400,000—250,000 years BP that gave rise to the capacity for an expanded system of representation in the brain; and secondly, a symbolic form of PF-LF representation of mental lexicon made possible by a high-speed acoustic-phonetic processing capability. Both events
were supported by an efficient memory system using neural substrates and connections (Nader, 2003). These two coincidental events make it possible for abstract concepts to be represented using arbitrary but shared sound-referent-meaning correspondences, thus giving rise to proto-language (Hurford, Studdert-Kennedy, & Knight, 1998). Operating within a social organisation, the early social functions of such verbalisations launched language on its evolutionary path. Verbalisations of this type gave the humans the evolutionary advantage in the language game when cooperative frameworks emerged (see Nowak, Komarova & Niyogi, 2001 for an analysis of the language game). In sum, language is a form-function amalgam resulting from the human cognitive apparatus that has clearly co-evolved with the brain through its potentiality as information carriers. As a result, it provides a basic template for establishing a reasonably efficient estimate of the entity-event relationships of the physical, as well as the perceived, world around us.

1.5.6 Linguistic processes in reasoning-based conceptual structures

For more than three decades, psychologists have suggested that comprehension involves correspondence between linguistic form and the situation it describes. When a person has comprehended a sentence, he is supposed to 'know what it means.' It follows from this that both the form this knowledge takes in memory (conceptual structure) and the process by which it is retrieved and used (cognitive operations), shape our understanding of the world around us, and language serves as the strategy/skill, or more likely, as an adaptation by which certain general processes of manipulating information by the brain give rise to reasoning and deduction leading to better understanding. In trying to trace these linguistic processes that examine the relationship between language and meaning in the ToM, we shall be concerned with the significance of 'meaningful learning' (Ausubel, 1968, 37) in acquiring knowledge, primarily how words, concepts and propositions generate meaning. We have investigated these properties of language acquisition in later chapters to deduce the nature of concept formation and subsequently how they are associated to provide the form and function of language together.

1.5.7 Language and cognitive functioning

The acquisition of conceptual structures in subject matter learning plays a major part in school education. In this context, most learning is dependent on verbal and other forms of
symbolic and representational learning. In fact, in the context of school education, language and the concomitant symbolic representation of knowledge through language are the focal points of the most complex cognitive functioning. It is amply evident that from four or five years onwards in a person’s life, language assumes a dominant role in cognitive functioning.

In addition, there are indications that a causal relationship exists between linguistic development as symbolic representation (the acquisition of phonology and structural-functional relationships\(^{15}\), internalisation of word-concepts, acquisition of more abstract and relational terms that leads to development in cognitive functioning as internalisations of logical operations) on the one hand; and the emergence of the ability to understand and manipulate relations between abstract vocal symbols and their concatenations and concepts without the benefit of any concrete experience, on the other made possible via a series of processing stages in the mind as in Figure 1.5:

![Sequential processing stages in concept formation/acquisition](#)

**Fig.1.5: Sequential processing stages in concept formation/acquisition (after Ausubel, 1968)**

### 1.5.8 Cognitive structures in second language acquisition

The study of cognitive structures involved in second language acquisition (SLA) started effectively with *Review of Verbal Behavior* (Chomsky, 1959). This is a suitable starting point to examine the theories regarding the acquisition of languages, since the views dominant for some one hundred years before that were cogently destroyed by Chomsky’s
analysis and criticism of the behaviourist position. The central claims of behaviourists were reevaluated in the light of Chomsky’s mentalist arguments. A wealth of studies came to light that suggested that language acquisition (LA) was developmental in nature, and it led to a substantial reworking of the role of L1 in L2 learning.

The issue of ‘language transfer’ (Kellerman, 1983; Ellis, 1994) became central to the investigation of the role of prior linguistic knowledge on the constraints of transfer. The manifestation of transfer as positive (facilitation) and negative (errors) to determine whether a discrepancy in the contrastive study of L1 and L2 have led researchers to believe that knowledge of a structure is not enough (Kamimoto, Shimura, & Kellerman, 1992) if learners do not know what it is that they know already (concepts/schemata). Therefore, cognitive knowledge plays a major role in learning an L2. Krashen (1983) and Newmark (1966) have shown that the learner invariably falls back on the previous knowledge when new knowledge is gained and is in the stabilisation phase, indicating clearly that older memory traces and their reactivation play a major role in L2L.

Considerable evidence is also available about developmental factors that work together in determining the course of language acquisition – transfer is selective along the developmental axis (Zobl, 1980). Studies have also shown that L1 influence on L2 acquisition is ‘developmentally constrained’ (Ellis, 1994, 332), that is, L2 acquisition occurs when the learner has attained ‘criticality’, in the sense that L1 effects are visible only when the learner has reached a certain stage of development that makes transfer possible. In addition, development may be retarded or accelerated or as and when a universal transitional structure in the L1 corresponds to, or does not match, respectively, the L2 structure. It is imperative that we understand the mechanism of SLA, which is possible only through our knowledge as to how the brain behaves when two (or more) source languages interact. The cognitive constraints referred to in the previous sections are those that delimit the use of previous knowledge in comprehension, production and analysis of new propositions, indicated in Figure 1.6 below:

15 We call this structural-functional competence, and not syntactic competence, because syntax is largely rule-based, whereas structural-functional competence is constraint-based and generates optimal outputs.

16 It is evident that the 6 general constraints on L1 transfer that Ellis (1994) discusses (language level, socio-linguistic factors, markedness, prototypicality, language distance and psychological typology, and developmental factors) must be taken into account to obtain a clearer understanding of the cognitive principles responsible for language acquisition.
This dynamic nature of SLA in the cognitive adaptive system provides for concept acquisition/formation through L2.

A key distinction maintained by researchers of language acquisition about whether their investigations are 'cognitive' or 'mentalist' was about the nature of the internal mechanisms (processes and strategies) responsible for language development. The cognitivists view the mental mechanisms to be general - language learning employs the selfsame cognitive systems of perception, memory, information processing, problem solving, etc., as other types of learning processes; and the strategies utilised to activate language learning are the same general cognitive strategies that are employed in treating other cognitive tasks as object recognition and acoustic discrimination. On the other hand, mentalist frameworks of language acquisition are based on the distinction between 'competence' and 'performance' (cf. Chomsky, 1965) as applied to linguistic knowledge and control procedures.

Traditional accounts of linguistic knowledge and their use, whether cognitive or linguistic, saw language as rules and representations. However, a break from tradition was achieved by McClelland and Rumelhart (1986). In variance with the traditional rules and representations approach, they saw linguistic knowledge as a network of related ideas and units, involving a complex set of interconnections. Their relatively simple connectionist network could account for a large body of past tense morphology without applying either modular architecture or rules. Their innovation did away with the distinction between learning

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17 It is important to distinguish between process and strategy to understand the cognitive perspective: process refers to "a dynamic sequence of different stages of an object or system;" and strategies can be treated as the plan to accomplish some process, partially or fully (see Ellis, 1994, 295 for details).
and procedural ability. This connectionist view is known as the **Parallel Distributed Processing (PDP)** approach. PDP theory is gaining ground both from the theoretical and experimental fronts now as more and more research delves into the principles of neural activation and the neuronal connections made during the processes of stimulus-response generation. The discovery of complementary neuronal pathways in the hippocampus and neocortex is indicative of the fact that there is a probable PDP in operation in learning systems (McClelland, McNaughton, & O’Reilly, 1995).

1.6 How does this functional property of the brain behave when confronted with processing a second language?

For some years now, claims of L2 processing being a predominantly LH activity dependent on L1 structures and cognitive mechanisms is gaining ground (see Perani & Abutalebi, 2005 for a review). It has also been argued elsewhere that L2 grammatical knowledge is mediated by a distinct neural system (involving a left temporal language circuit) dependent, as it is, on declarative memory systems (Ullman, 2001). A recent study of neuronal organisation of L2 has revealed an age-of-acquisition (AoA) dependent proficiency effect in multilingual volunteers (Perani et al., 2003). Perani et al. showed that differential exposure to a given language might affect the cortical representation, even when the degree of proficiency is controlled. This exposure-related differentiation was seen in the left dorsolateral frontal cortex, in line with other studies on monolinguals (see Price, 2000 for a review). The conclusion one can draw from such evidence is that experience and practice on language tasks has its effect on proficiency attained in L2 processing, and could be reflected in the extent of frontal cortical activity.

Several neuroimaging studies have indicated how the functional organisation of the second language (L2) changes during the acquisition process. For example, in early stages of learning, L2 vocabulary items are processed primarily through association with their translation equivalents in the first language (L1), whereas in later stages of learning they are more directly concept-mediated, i.e., associated with their meanings (Chen & Leung, 1989; Chen, 1990; Dufour & Kroll, 1995; Kroll & Stewart, 1994; Potter, So, von Eckhardt, & Feldman, 1984). In these studies, L1 and L2 vocabulary are thought to increasingly access a common semantic system as a person becomes proficient in L2. A recent functional magnetic resonance imaging (fMRI) study (Illes et al., 1999) implicates the frontal lobe for both
monolingual and bilingual processing, indicating thereby that two languages could possibly have a common semantic neuronal representation in the brain.

It would therefore be reasonable to conclude, based on such evidence, that environmental structures are abstracted through features (identified by their functional properties and encoded in terms of neuronal response as spikes) and are increasingly incorporated as novel features (as a result of complex, dynamic, nonlinear operation of the functions comprising the act of language comprehension) during complex psychological processing, thereby achieving featural discrimination as well as functional integration of neuronal processes, observable as electrophysiological response-function states of spiking neurons. On the correlation between the observed behaviour and the neuronal response, Illes et al. (1999), in particular, confirms that categorisation tuning, previously thought to influence perceptual categories (Goldstone, 1994a,b), are demonstrably influential in higher level cognitive (conceptual) processing as well. This makes us wonder whether the same basic processes regulate all kinds of cognitive activities, from the most simple to the most complex. In a recent study, Takegata et al. (2005) report that the parameters of the mismatch negativity (MMN) response varied according to the position of the deviant tone repetition with respect to tone groups. However, when the repeated and the preceding tone were separated by a pair boundary, there was a delay or lessening, or even complete erasure of the MMN response. These MMN effects were probably partly caused by the longer pre-deviant interval preceding across than within-group tone. These results thus support the hypothesis that temporal grouping affects the memory representation of inter-tone relationships, hence they are most likely to be useful in determining the neural mechanisms that are responsible for language comprehension. However, no definite conclusions can be drawn for cortical organisation of L2 on the basis of these studies alone.

1.7 ‘Syntax’ no more: Associativity in learning language

1.7.1 Language acquisition as a consequence of PF-LF interactions and resultant neural codes

In addition to the abovementioned approaches, studies that investigate possible neurological bases of the nature of linguistic categories in cognition makes connections between memory and other cognitive and linguistic systems. For example, Pinker (1999) argues that the regular-irregular distinction (represented by temporal-frontal lobe networks
implicated in memory associations by neuroimaging), exemplifies a more general feature of the human mind – that cognition is supported by two types of categories – classical (regular words) and fuzzy (irregular words). Members of the classical category use symbol combination computations for stable communication; and associative memory is the core mechanism for representing the fuzzy categories. Both mental mechanisms are integral requirements for an efficient cognitive system. Pinker's (1999) hybrid approach asserts that both mechanisms are simultaneously available to the speaker/hearer. If that is the case, language acquisition transcends the boundary of psycholinguistic objects (as exemplified by initial mental state, \( S_0 \) transforming into an end-state, \( S_f \) \( S_0 \rightarrow S_f \)) denoted by the increase in the competence and performance of the sound-meaning associations of a language in real-time) and can be construed as a mapping of the functional property of neuronal ensembles/connectivity in terms of its energy and metabolic dynamics, spectral signature of spikes as representing behavioural correlates, and hence as activation patterns of neuronal ensembles/connectivity. Within such an approach, then, the conceptualisation of language acquisition eliminates the need for a syntactic level of description by eliminating the notion of grammatical construction as a virtual conceptual necessity ('minimalism,' for details, see Chomsky, 1993, 4-5). What remains is an exposition of language as a biological faculty, a resultant of the general properties of functioning of the neuronal ensembles/connectivity, and hence open to investigation by the 'hard' problem of characterising what may be termed as the neurobiology of linguistic cognition. In such a model, the linguistic functions are characterised by construction of coordinated representations at multiple levels such as involving multiple brain regions, and requiring a high degree of cooperation between various brain regions, including the PFC and MTL, including TPC. Such widespread activity in the cortex may be interpreted in terms of temporal phase locking and represents a globally distributed cortical signal, that can be maintained as a network or modulated as a whole (Varela, Lachaux, Rodriguez, & Martinerie, 2001; Friederici, Opitz, & von Cramon, 2000; Shulman, Tansy, Kincade, Petersen, McAvoy, & Corbetta, 2002).

Recent reports from primate visual studies indicate that an experience-driven neural system of top-down perceptual learning is at work in primary visual cortex (V1) in monkeys trained to discriminate shape (Li, Piëch, & Gilbert, 2004), thereby implicating stimulus attribute-dependent processing throughout the time course of stimulus presentation, as is shown to be the case in operations selectively recruiting the primate 'mirror neurons' that
become active while imitating actions (found in the F5 region of the macaque brain and analogous with the premotor cortex and Broca's area in humans) (Williams et al., 2001). Such studies give rise to speculations about whether animals other than humans also have RTM. In humans, the emergence of symbolization in early childhood development also has a transformative effect on the nature of children's interactions with other people, and hence in their opportunities for learning, that is brought about by the recourse to language from the second year of one's life (see DeLoache, 2004). A recent study involving post-learning auditory discrimination task in humans indicates attentional modulation in auditory perception and showed rapid adaptation to repeated sounds in functionally dichotomous cortical mesial and lateral fields of the auditory cortex (Petkov et al., 2004). Coming, as it does, on the heels of compelling evidence of the basic uniformity of neocortical structure (Rockel, Hiorns, & Powell, 1980), the generic capacity for infinite recursion that evolved out of a refinement allowed by the increase in connectivity of the pyramidal cells of the cortex (Treves, 2005), is seen to be contributing to the turning on and off recurrent cortical activity that favours formation of the synapses in the human cortex (Kalisman, Silberberg, & Markram, 2005).

Such empirical evidence of functional attractor dynamics leads to the logical possibility of frontal latching networks (Treves, 2005) as a favoured mechanism for processing complex information streams may form the basis of memories that give rise to language comprehension (Pulvermüller, 2002). This processing mechanism could also be interpreted with reference to the narrow sense of the faculty of language (FLN), if seen in the light of the internal structure of language. A key component of FLN is the conceptual-intentional interface of the mental representation that is built upon the sensory-motor interfaces, buttressed, as they are, by potential adaptations that generate internal representations and maps them onto the (formal) semantic system. There is general agreement that a core property of FLN is infinite recursion, a property that allows creativity and generativity in language. This recursive capacity is reducible to pairings of acoustic signatures and meanings, a scheme that has been recognised by the "philosophers of language" (de Saussure, 1974). We see then that if FLN is considered a part of FLB (see Lieberman, 1996) (since the sensory-motor systems are considered to have specifically evolved for linguistic adaptation), then it would not be too difficult to assume that FLN is the abstract computational system alone (see HCF), and the mechanisms underlying it are some "subset" of those underlying FLB. But if this computational system is to make any sense to the organism, it must be biologically valid at both logical and operational levels.
Hence, the pairing of the acoustic properties of linguistically meaningful sounds to its operational memory is inevitable. And since memory operates via molecular mechanisms, its characterisation for language would not be far behind.

1.7.2 The solution: Combinatorial meanings

To solve the problem of human knowledge representation and its facilitation, a different mechanism for information processing was proposed by Miller (1956). Referring to the human brain’s ability to process only small ‘chunks’ of information at a time, they focussed on the problem of acquisition of large amounts of information as possible most efficiently through linguistic recoding, as it is the most powerful mechanism of processing information due to its combinatorial nature. Further, as Miller & Selfridge (1950) had so emphatically argued earlier,

...chunking is accomplished by grouping a series of words that are sequentially dependent...into larger units (phrases), and then remembering them...The recoding scheme under these circumstances is derived from the contextual constraints that characterise linguistically connected discourse that are built into the structure of language and implicitly learnt by all those who use it. The contextual constraints are defined in terms of “dependent probabilities”.

(Miller & Selfridge, 1950, Qtd. Ausubel, 1968)

The probabilities are determined by context, and these contextual dependencies facilitate the understanding of meaningful material through the associations made by the language with the mental schemata in the learner, either by adding to it, or modifying it, known as concept acquisition and assimilation, respectively.

The approach followed by Ausubel (1968) in defining meaning combination mechanisms is somewhat different: he establishes how various relevant ideas/concepts that cannot be part of, or constitute other ideas, give rise to combinatorial meanings. He emphasises that potential meaningfulness of any idea/concept arises in part due to their non-arbritrariness and substantiveness, and can be related to,

...a broad background of generally relevant content in cognitive structure by virtue of their general congruence with such content...they are not relatable to particular relevant ideas within cognitive structure; and this availability of only generally and superficially relevant content in cognitive structure presumably makes combinatorial propositions less relatable or anchorable to previously acquired knowledge, and hence initially more difficult to learn than subordinate or superordinate propositions....[But] they manifest, once adequately established, the same inherent stability...

(Ausubel, 1968, 53, _italics_ Author’s)
He later relates it to learning of concepts in the following words,

Since propositions can presumably learned and retained most readily when they are subsumable under specially relevant ideas in cognitive structure, and since the hierarchical organisation of cognitive structure is itself illustrative of the subsumptive principle, it seems reasonable to suggest that the subsumptive mode of learning be utilized wherever possible.

(ibid., 54)

Therefore, cognitively oriented learning and pedagogical approach – a structured hierarchical organisation of meaningful subject matter with ample reference to the learner’s previously learnt concepts – gives rise to stable combinatorial meanings and forms the basis of scaffolded curriculum design. Apparently, this dynamism of memory that boosts learning is activated by previously held memories, via dynamic interactions between various brain states and mechanisms, and between various systemic regions of the brain – the hippocampus and the neocortex (Nader, 2003). Nader has supported that reactivation can return fixed, consolidated memories to a labile state similar to STM, where it can be modified, updated and changed. Hence, for effective acquisition and stabilisation of conceptual structures, its memory needs to be reactivated. It has also been suggested that restabilisation of memory structures would be faster than construction of new synaptic connections. (Bailey & Kandel, 1993). There is also growing evidence that the hippocampus and neocortex regions of the brain provide the locations of the dynamicity of memory retrieval: older memories that are ‘remote’ are neocortex-dependent, while recent memories are hippocampus-dependent (Scoville & Milner, 1957; Anagnostaras et al., 2001; Eichenbaum et al., 1994; Squire & Alvarez, 1995). The workings of the STM-LTM mechanism thus operate in terms of dynamic switching of the memory states depending on which area of the brain is activated. Memories are thus organised in terms of both cellular (inactive-active) as well as systemic dynamic reconsolidation (neocortex-hippocampus) processes (Debiec et al., 2002).

Nader (2003) goes on to provide strong evidence that even remote memories can be returned to a labile (hippocampus-dependent) state and remain so in that state for several days; priming of the learner’s memory would thus necessarily form a distinct secondary18 memory trace, and so, reactivation of remote contextual memory undergoes further systems

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18 The original or primary memory trace is formed when new learning takes place.
consolidation. Hence, consolidation and reconsolidation, when seen with respect to acquisition of grammatical structures (i.e., structural-functional competence) and content learning respectively, are favourably achieved when scaffolded and occur simultaneously. Hence, under formal learning situations, the development of curricula should be geared towards providing the learners the cues to augment the growth of associativity among different input systems of form and function in unison. We shall see in the next chapter how these environmental factors interact in an actual teaching-learning situation.