THE EFFECT OF THE KNOWLEDGE BASE ON THE ACQUISITION OF MEMORY STRATEGIES

by

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Summary

The dissertation explores the effect of the knowledge base on the acquisition of memory strategies. It is postulated that 'salient' categories - highly elaborated categorial structures in the knowledge base - facilitate memory performance so that elevated levels of clustering and recall, and an emergent organisational strategy, can be expected in young children's memory performance with such categories. Two multitrial, free-recall experiments were conducted to test the hypothesis. The first experiment analysed the memory performance of preschool children and adults on category type (salient versus nonsalient categories). The second experiment analysed the effect of category saliency on memory search processes. The experiments yielded evidence suggesting that highly salient items in the knowledge base are easily activated during the course of memory retrieval, resulting in enhanced levels of recall with such items, and the early manifestation of an organisational strategy.

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Chapter 1
General overview

Memory constitutes a particularly dynamic domain of psychological research and is actively pursued in cognitive, physiological and developmental psychology. Part of the interest in memory derives from the central role that it plays in theories of learning. The ability to retain information about the world is a fundamental aspect of the human cognitive system and a prerequisite for learning, because it is impossible to acquire a stable body of knowledge about the environment unless the information is encoded in some or other representational system. It is not surprising therefore that many researchers in psychology proceed from the assumption that there is a logical affinity between memory and learning, and consequently that memory and learning form a single domain of research (see e.g. Horton & Mills, 1984).

Given the close connection between learning and memory, memory research can also serve as a source of hypotheses about cognitive development. This is because the process of cognitive development entails a gradual accumulation of knowledge about the world and this knowledge must be stored in memory. Research into the developmental aspects associated with the representation and processing of knowledge in the memory system will therefore also yield insight into the mechanisms underlying cognitive development. Clearly a coherent theoretical model of memory development will make an important contribution to our understanding of the processes underlying learning and cognition. Yet, despite an intensive research programme and substantial progress in uncovering some aspects of memory, a true understanding of the dynamics of memory development continues to elude us.

The main theoretical objective of this dissertation is to generate insight into the principles underlying early memory development. The study focuses on the development of knowledge structures in permanent memory and investigates their role in facilitating memory retrieval in the context of a free recall paradigm. More specifically, the research reported in the dissertation is concerned with the effect of category saliency on the early development of clustering strategies in free recall. The basic aim of the overview is to sketch the general theoretical framework within which the study is conducted. In the subsequent chapters a more detailed theoretical motivation for the study will be given.

1.1 The structure of memory

In psychology a distinction is usually drawn between different types of memory. Most researchers seem to agree that memory is not a single monolithic entity, but a complex set of interdependent processes and subsystems. Memory is now commonly partitioned into a working memory and a permanent store. The latter is usually conceptualised as involving a declarative and a procedural component, while the declarative component is divided into a semantic, and an episodic or autobiographical subsystem (Shachter, 1988).

The distinction between a semantic and an episodic subsystem was originally postulated by Tulving (1972), who suggested a conceptualisation of memory comprising two different categories of declarative (i.e. factual) memory. He posited a semantic system dedicated to the processing of language, embodying knowledge of verbal information, conceptual categories and algorithms for manipulating such symbols, and an episodic system devoted to the processing of temporally dated information about events and the subjective knowledge associated with them. In his initial formulation of the distinction Tulving claimed that it captured the essence of two logically separate memory systems and that the proposed distinction enjoys empirical support (Tulving, 1983).

However, the conception of memory involving a logically separate semantic and episodic system has limited explanatory value in developmental psychology. This is because the distinction fosters a static view of the memory system and does not lend itself easily to a description of the dynamic aspects of memory development. The problem is that the development of abstract conceptual structures (i.e. semantic memory), logically entails some or other specific event (i.e. episodic memory) in which the content knowledge is anchored. For instance, a child clearly requires exposure to at least one instance of a semantic category in order to be able to form an abstract conceptual representation of the category. The point is that there is an interaction between the semantic and episodic components in early memory development which makes the postulation of completely separate systems problematic.

Tulving (1985) himself subsequently came to a realisation of these problems and opted for a less rigid formulation in which he contended that the two systems are probably interdependent, rather than logically distinct. He maintained, however, that the proposed distinction has heuristic value, and can be invoked for classifying memory research in terms of the two different domains. In view of the interaction between semantic and episodic memory in memory development, developmental psychologists now prefer to use the more generic term **knowledge base** to denote the contents of permanent memory (Bjorklund, 1987). This term is also used in this dissertation, although the focus is more specifically on the structures and processes governing the development of semantic memory. The study addresses the initial elaboration of conceptual categories in the knowledge base, and explores the way in which knowledge of categorial relations promotes the development of organisational strategies in the recall of verbal material.

1.2 The organisation of the knowledge base

A central tenet in many psychological approaches to memory is that the knowledge in permanent memory is highly organised, instead of simply associated in *ad hoc* ways. The organisational approach is perhaps most clearly articulated in gestalt theory. The gestalt psychologists contended that the memory system is ruled by principles of organisation and that the perceptual system groups incoming stimuli on the basis of relational properties such as proximity, similarity, direction and prägnanz (i.e. closure) (Marx & Hillix, 1979, p. 184-185). They further argued that the durability and accessibility of the resulting memory trace is largely determined by its underlying cohesiveness, in other words its continued existence as a unit or gestalt (Postman, 1972).

The gestalt position has been criticised for its overly subjective and qualitative approach and lack of quantitative and testable formulations (Marx & Hillix, 1979). Yet the emphasis on organisational factors has endured and now attains an almost axiomatic status in memory research. In fact, several lines of research converge on the view that human memory is a highly organised system.

This organisational perspective receives support both from empirical research and theoretical analyses. Empirical research on semantic categorisation and retrieval from long-term memory suggests that the human cognitive system is structured in terms of different content areas (Bower 1970; Puff 1979). There is ample evidence showing that memory is organised on the basis of semantic domains such as categories (*animals, furniture,* etc.) and schemata (stereotypical information associated with *restaurants*, *hospitals*, *supermarkets*, etc.), and that these organisational structures mediate inference and enable the individual to construct a mental model of the world (see Johnson-Laird, 1983).

Theoretical analysis also indicates that unless the memory system is organised, semantic inference could become intractable. For instance, by trading on our past experience associated with, say, restaurants, we know that when we have just been seated at a restaurant and a waiter asks us what we want, he means that we should place an order from the menu. In the absence of such preknowledge, a host of irrelevant inferences would have to be considered (e.g. that he wants to strike up a conversation, that he is handing out presents, that he literally wants us to tell him all our personal wishes, etc.).

The point is that the cognitive system can only eliminate irrelevant inferences if it has recourse to a representational structure (i.e. content knowledge) to guide the reasoning process. Indeed, Schank (1982) postulates that memory is a dynamically organised system because he found in computer simulations that the process of semantic inference can easily lead to a 'combinatorial explosion' of irrelevant inferences unless the relevant content (i.e. domain-specific) knowledge can be invoked to constrain them (see King, 1989; Glassman, 1988).

1.3 The ontogeny of organisational structures

If we assume that human memory is a highly organised system, the nature and origin of the structural elements in memory need to be specified. The problem confronting developmental researchers is therefore to account for the initial acquisition and elaboration of the knowledge base.

Logically there are at least three different positions on this issue:

One alternative is simply to deny that conceptual structures are acquired and to postulate an innate system in which concepts are genetically prewired. This is roughly the position taken by Fodor (1975, 1981). This approach advances a deductive model of development which precludes the acquisition of completely new structures, and only permits knowledge to be extended via deductions from an existing knowledge base. However, Fodor's approach has been criticised for its failure to account for concepts such as *gene* or *quark* which have evolved in the course of scientific innovation. To assert that children are born with preknowledge of such concepts is tantamount to claiming that the theories in which the concepts originated are innate, which seems rather extravagant (see Churchland, 1986).

A second possibility is to argue that cognitive structures undergo large-scale maturational changes at specific, predetermined periods during the course of development. Such changes permeate the whole knowledge base and bring about widespread and dramatic changes in the conceptual system. This position is therefore based on the assumption that general-purpose algorithms for manipulating knowledge suddenly emerge at given developmental stages, and characterises Piagetian approaches to memory and cognitive development. However, the position has been criticised on the grounds that it merely transfers the locus of change to the concept of *maturation*, which is left unexplained, and consequently that it offers a description rather than an explanation of conceptual change (Brainerd, 1978).

A third and more modern approach postulates that knowledge structures evolve on a domain-specific rather than a domain-general basis. In terms of this position no general-purpose algorithms for manipulating knowledge exist. Rather, procedures and heuristics are invented in the course of dealing with specific microstructures or content areas in memory so that the knowledge base expands in a gradual, incremental manner rather than in a sudden and dramatic way. Although the latter approach is inductive rather than deductive and is based on the assumption that cognitive development is governed by some kind of learning process (in contrast to deductive models which eschew the problem of learning), it does not carry the implication that innate factors are irrelevant in conceptual development. Rather, it is now generally accepted by many cognitive researchers that induction is probably subject to some fairly specific constraints germane to the human species (e.g., Keil, 1989; Keil, 1990). For instance, the investigation of early lexical acquisition and conceptual development suggests that children rely on specific ontological assumptions about the extension of (i.e. the set of elements included in) semantic categories.

Thus Markman (1989) observes that very young children (1 to 3 years of age) enter the language learning game with considerable theoretical baggage and proceed on the basis of the assumption that each object has only one label. Markman calls this constraint on word learning the 'mutual exclusivity bias', and argues that it serves to reduce the number of hypotheses about word meaning a child needs to entertain when learning a new word. When an adult points to an object and labels it, the novel term can refer to a part of the object, or its substance, colour, texture or size. The acquisition of word meanings would be a very difficult, if not impossible, task if all these alternative hypotheses have to be considered each time a new word is heard. Instead, children may initially constrain word meanings by assuming that a novel label is likely to denote the whole object, and not its part, substance, size or other properties (see also Merriman & Bowman, 1989; Markman & Wachtel, 1988).

Two additional claims concerning the initial ontological biases of children may have about conceptual structures derive from Rosch's (1975, 1978) programmatic work on categorisation. She argues firstly that there is a specific entry point, called the basic level of categorisation, into the cognitive system which maximises the similarities and differences between different semantic categories. The implication then is that children will find it easier to acquire basic level concepts than concepts located at higher or lower levels of the conceptual hierarchy. For instance, the words *cat, dog, horse* are basic level concepts whereas *animal* is a superordinate concept and *siamese cat, bulldog, racing horse* are subordinate concepts. What Rosch in effect claims, is that children will acquire a concept such as *cat,* which is in the middle of the conceptual hierarchy, before they form the abstract concept *animal* or make a conceptual distinction between different kinds of cats. Secondly, Rosch contends that certain words are particularly good examples of a category and are consequently associated with clusters of semantic properties typical of the category. For instance, a sparrow is a more typical member of the category *bird* than a penguin, because a penguin cannot fly. These typical members of a category are called prototypes, and there is now evidence that children acquire them prior to the atypical members of the category (e.g., Bjorklund & Buchanan, 1989). The claim is therefore that children find prototypical members of a category easier to learn than non-prototypical members.

The research described in the dissertation is situated within this general theoretical framework and draws extensively from the work on prototype theory. The hypothesis developed is that children will find certain semantic categories more salient and inductively richer than others. The basic idea is simply that the finding about prototypical elements in a category applies recursively to the conceptual structure as a whole. In other words, it is posited that certain categories are more 'prototypical' for the young child, and that these categories will be elaborated prior to other less salient categories, so that the knowledge base expands on a differential basis. This theoretical claim is set out in more detail in Chapter 2.

The discussion so far has concentrated almost exclusively on the structural aspects of the knowledge base. However, some assumptions about the processing of information in the knowledge base is also required in order to adequately account for the processes underlying the early acquisition and refinement of conceptual structures.

1.4 The activation of knowledge in permanent memory

In terms of the theory outlined above it is claimed that certain categories are particularly salient for young children, and that such categories are endowed with a special status during the course of early cognitive development. It can also be conjectured that these categories will be easier to access during memory tasks, so that memory recall can serve as an objective test for the proposed theory. In this study it is hypothesised that children will exhibit higher levels of recall and clustering in memory tasks associated with salient categories, than with nonsalient categories, and that this pattern of performance would obtain even if the nonsalient categories contain prototypes.

The conjunction of these two hypotheses (about the representation and access of categories) presupposes some particular processing mechanism. In this study it is assumed that the retrieval from the knowledge base is governed by the process of spreading activation. The notion of spreading activation has a long history in psychology (cf. Collins & Loftus, 1975; Anderson, 1983) and has been proposed to overcome the difficulties inherent in earlier information processing models containing a central executive (a mechanism that controls the flow of information). One of the problems with the earlier models is that the assumption of a central executive reifies the control structure of the model and acts as an undefined homunculus (a little man who makes all the important decisions; cf. Postman, 1972). Postulating a homunculus leads to an infinite regress (the homunculus needs another homunculus to tell him what to do) so that subsequent models have attempted to do away with the notion of a central executive. The theory of spreading activation constitutes one such attempt.

In spreading activation theories of memory processing a richly interconnected network of semantic relations is posited with weighted links between concepts. It is customary to use a graph-theoretical representation in these approaches and to represent concepts as vertices (called nodes) and the relations between them as edges (called arcs or links). The idea then is that conceptual relations are accessed in memory tasks or language understanding via a process of activation which spreads automatically through the network in such a way that the path connecting closely related nodes is traversed more quickly than the path joining less closely related nodes. This weaker relation between concepts is generally represented by a lower weight on the link joining them. An additional assumption is that activation spreads on the basis of some threshold function (fixing the extent and duration of the activation) so that the probability of closely associated concepts activating one another is much higher than is the case with nodes further apart in the network (see Anderson, 1983).

The spreading activation paradigm has been applied to memory development by Bjorklund (1987) and is also adopted here. The idea is that initial processing of categorical structures is a fairly automatic process governed by the associative links between the members of the category. We can think of the cognitive system as a network of associative relations and of the energy driving the system as a limited pool of cognitive resources which spreads automatically through the network when activated. During the course of cognitive development, more and more associative relations are forged in the conceptual system and higher-level, more hierarchical structures such as schemata and well-elaborated categorial structures are established. The better organisation of the higher-level semantic structures and the stronger associative relations and pathways linking various structures and concepts in the conceptual system means that cognitive processing becomes increasingly automatised during the course of development. As a result of this optimisation of the processing mechanism, cognitive resources will become available for metamemorial tasks such as organisation, rehearsal, elaboration and the development of retrieval plans. This in turn means that a better and more flexible use of the memory system will occur during cognitive development, resulting in enhanced performance on memory tasks.

1.5 Summary of theory and proposed research

This study is situated within the general theoretical framework sketched above. It is assumed that categories are elaborated on a differential basis and that highly salient categories are extended first. Such categories exhibit better organisation than non-salient categories in memory and are marked by strong semantic associations. Because of the fairly elaborate semantic structure characterising salient categories it can be conjectured (a) that they will be easier to access during recall and (b) that the strong associative links joining members of the category together will result in a limited form of clustering in the recall output (e.g. Lange 1978). Moreover, the enhanced semantic structure associated with salient categories implies that they can be processed in a fairly automatised manner and consequently that they will require less cognitive resources than non-salient catergories. The general picture is therefore of a cognitive system which develops on a domain-specfic basis in that specific semantic structures are salient in early memory development, are connected by strong associative relations and manifest an emerging hierarchical structure. The elaborate structure of these categories facilitates processing (they can be accessed in the system) and promotes the efficient functioning of the conceptual system.

This general theory is tested in this study on the basis of a multitrial, free recall paradigm (Murphy & Puff, 1982). The procedure employed involves the presentation of two lists of words to the subjects, who are then required to recall them over three trials. Both lists consist of five members from each of four different semantic categories. One list contains categories that can be regarded as salient to children (as pre-experimentally established) and the other list consists of categories which are non-salient (to the children), but contain members that normative studies have shown to be prototypical elements of the categories concerned. The two lists are presented to three groups of subjects. A group of 4-year-old children, a group of 6-year-old children and a group of adults. The research hypothesis is that the children will find the salient categories easier to process (as revealed by number recalled and amount of clustering), but that different patterns of performance will be observed with the adult subjects. This is because categories that are salient to children are not necessarily equally salient to adults. In this case it is conjectured that the adults will exhibit better recall with the prototypes from the categories included in the other list.

The first experiment focuses on different patterns of performance that can be expected when children and adults are tested on the free recall of categorised lists. Assuming that such differences are found, it is also important to establish whether the differences are due to encoding or to retrieval processes, as both these factors can affect recall. A second experiment addresses this issue, and also explores other aspects of children's memory performance. This experiment is performed with a different sample of children, and tests for a hypermnesic effect (i.e. that gains in recall will be observed over trials even if the subjects are not given renewed opportunities for encoding the relevant stimuli). The experiment has two main objectives.

Firstly, it attempts to show that the problems children experience in the course of early memory development are not solely attributable to a storage deficit. In other words, it is intended to demonstrate that children's impaired memory performance (relative to adults) does not only derive from an inability to attend to and to store the relevant stimuli in the memory system, but concerns a more general retrieval deficit. The issue concerning the relative contributions of storage and retrieval processes to children's memory performance is important, because it is assumed in this study that children's impaired memory performance derives at least partly from difficulties in activating (i.e. accessing) the relevant items in memory. Now, if a hypermnesic effect does obtain with the children, we have reason to believe that the recall deficit shown by children in free recall is to some extent due to the inefficient use of retrieval strategies.

Secondly, the experiment is aimed at exploring the nature of cumulative memory search processes on the recall of salient and non-salient categories. It is predicted that different levels of hypermnesia will be found with salient and non-salient categories, because the former will be easier to activate during the memory search processes. In other words, the hypermnesia test constitutes a means of exploring the way in which items from different categories are activated during the course of memory retrieval.

The structure of the dissertation is as follows: The second chapter provides a review of the theoretical and empirical literature concerning the role of the knowledge base in memory development. The theory underlying the empirical study and the research hypotheses emerging from it are also developed in this chapter. The third chapter is concerned with the methodological procedures followed in the empirical study, and describes two experiments designed to test the hypotheses developed in Chapter 2. The fourth chapter is devoted to a statistical analysis of the results obtained, while the results of the empirical study are discussed, and some of the general implications of these results are drawn, in the fifth and final chapter.

Chapter 2
Review of the theoretical and empirical literature

A large body of research has been amassed documenting developmental changes in memory performance. This research seems to suggest that there are fairly general improvements in children's abilities to execute memory-related tasks during the period of cognitive development (e.g. Wellman, 1988; Schneider & Pressley, 1989). In contemporary psychological theory the development of the memory system is usually attributed to the acquisition and elaboration of memory strategies such as the rehearsal (i.e. vocal or subvocal repetition) and organisation (i.e. grouping) of the material to be remembered (Ornstein, Baker-Ward & Naus, 1988). Memory strategies are generally defined as deliberate plans intended to improve performance, and subject to conscious evaluation (Bjorklund, 1988). These strategies are thought to enhance memory performance because they lead to the formation of efficient retrieval schemes for the material to be remembered. On this account, children's memory performance improves because they become increasingly strategic with age. That is, they gradually learn to apply appropriate mnemonic strategies effectively during the execution of memory tasks.

Although the view that memory development is mediated by the acquisition and increasingly effective utilisation of memory strategies permeates the psychological literature, it suffers from at least two defects. Firstly, the term *strategy* lacks a clear definition, so that it is not always apparent what counts or does not count as a memory strategy (Bjorklund & Buchanan, 1989). In fact, some researchers go so far as to drop the requirement that strategies be considered voluntary (i.e. conscious) operations, and only stipulate that strategies 'be potentially available to consciousness' (e.g. Pressley, Borkowski & Schneider, 1987). Secondly, most of the research on memory strategies has focused on school-going children, and in the case of such children the acquisition and elaboration of strategies are typically attributed to the demands placed on memory by the educational system (e.g. Bjorklund, 1985). Much less is known about the emergence and refinement of strategies in preschool children, and indeed about the factors governing the initial stages of memory development.

This review addresses the latter issue and examines the hypothesis that early improvements in children's memory are mainly the result of developmental changes in the organisation of their conceptual knowledge. The assumption that conceptual knowledge is a factor that influences memory performance is a theme that now dominates much of the current research on memory development. Essentially the claim is that young children's performance on memory tasks is impaired, not only because they lack sophisticated memory strategies, but also because they have relatively impoverished knowledge bases (see e.g. Bjorklund, 1987; Chi & Ceci 1987; Ornstein & Naus, 1985). Children have rather limited experience of most things in the world and can consequently be regarded as 'universal novices' (Brown &

DeLoache, 1978). It is this lack of knowledge, so the argument goes, rather than simply inadequately developed memory strategies that impairs children's memory performance.

The basic assumption underlying this line of research is that children are learning more about the world and about their language and that the knowledge they gain plays an important role in their ability to acquire, retain and recall information (see Ornstein & Naus, 1985). A corollary of this assumption is that the acquisition and elaboration of knowledge enhance memory performance because in the process conceptual structures become more organised and better integrated, so that children can search and access stored information more efficiently (Chi & Ceci, 1987, p. 93). The research goal is then to uncover the way in which systematic changes in the content and organisation of the knowledge base influence memory abilities.

It is important to note that knowledge-base theorists do not claim that knowledge is the only factor affecting young children's memory performance. They acknowledge that memory development is probably a function of a number of interacting factors such as the knowledge base, an emergent strategic ability, and individual aptitude (e.g. Siegler, 1990). The point is rather that some developmental psychologists now argue that knowledge is an important contributing factor to early memory performance, and one that is easily overlooked or underestimated in many psychological approaches to memory and cognitive development.

Chapter 2 charts some of the progress which has been made in research on memory development and provides an interpretative review of the role of the knowledge base in facilitating memory performance. The scientifically respectable, and probably most logical, way to proceed would be to describe the theoretical model and then to show how it can be applied to make accurate empirical predictions across a wide range of tasks and situations. Such an approach is unfeasible here because the theory underlying research on the role of the knowledge base in memory development is fragmentary and inchoate, and has not yet attained the status of a coherent and precisely articulated theoretical model. At best we have a general framework, a broad theoretical context in terms of which some sense can be made of the empirical data, and which guides research and theory building in this area (see Baddeley, 1986, p. viii; Carey, 1989). The basic aim of this chapter is to sketch the theoretical framework and to clarify its role in shaping current research on memory development. The chapter begins with a few preliminary observations about memory and memory development, reviews some of the relevant theoretical and empirical research in this area, and then sets out the theoretical framework associated with research on the role of the knowledge base in the development of memory. After this, a few unresolved theoretical issues are identified and the theory underlying the empirical study, which will be described in Chapter 3, is developed.

2.1 Some preliminary observations about knowledge and memory development

The notion that knowledge mediates memory and cognition is intuitively compelling. Effective reasoning clearly depends on a large body of accessible and usable knowledge about the target domain (see e.g., Frensch & Sternberg, 1989; Lenat & Feigenbaum, 1991). In fact, knowledge seems to be an integral part of any cognitive system. When we study cognitive behaviour, issues such as how concepts are structured in the mind, how they develop and how they are used in thinking and behaviour invariably crop up (Schank & Abelson, 1977, p. 1). Knowledge is also implicated in memory performance. It is trivially true that it is easier to memorise material from highly familiar domains than from domains with which we are completely unfamiliar (see Bjorklund, 1987). For instance, English speakers will generally find it much harder to memorise a list of Japanese words than an equivalent list containing English words. Such differences in cognitive performance can obviously be attributed to differences in the amount of knowledge available about the target items.

However, construed in this broad way the assertion that knowledge influences memory performance may seem rather vacuous. Indeed the notion of knowledge sometimes has a rather nebulous quality in the literature, and is often invoked in a *post hoc* fashion to explain individual or age-related differences in performance that cannot be satisfactorily attributed to other factors. This problem is aggravated by the fact that the term *knowledge* is difficult to operationalise. What we call 'knowledge' is nothing less than the entire fabric of common sense and beliefs subsuming an individual or a community's understanding of the world. In its wider sense knowledge involves familiarity with language and the facts, experiences, customs, ideas, abstractions, associations, assumptions, rules and procedures needed to understand individual and collective observations of the world (see Patterson, 1990). Considered in this way, it is a global capacity, a general factor that determines intelligent thinking. Some theorists have even argued that this capacity is too global, that general knowledge involves such a complex and dynamic (i.e. changing) constellation of interconnected beliefs and experiences that it is simply not amenable to scientific investigation (e.g. Fodor, 1983). However, this conclusion is overly pessimistic, and some of the recent work in cognitive science shows that knowledge can indeed be studied systematically, as we shall see in Section 2.4.

In contemporary cognitive theory knowledge is usually approached by conceptualising it in terms of cognitive structures and processes. The cognitive structures are representational schemes such as concepts, categories, networks, frames, schemata and scripts (see Shoben, 1988). The cognitive processes are generally taken to be strategies, rules, heuristics, functions or innate mechanisms for acquiring, organising and using knowledge. The assumption is that knowledge is represented in the mind in some sort of organised form, and that cognitive processes act upon these representations during the execution of cognitive tasks. In the context of memory research, this means that the research problem reduces to the explanation of memory functioning in terms of the underlying cognitive mechanisms responsible for the representation and utilisation of knowledge. On this account then, memory develops because there are age-related changes in conceptual representations (e.g. more features are added, structures become more complex, the nature of organisation changes), and in the efficiency with which cognitive processes are executed (see Bjorklund, 1987).

Admittedly this description is rather vague and abstract. In order to get a better idea of the general research paradigm, and the particular form it takes in psychological approaches to memory development, we need to digress a bit and consider some of the theoretical currents that have shaped it.

2.2 Theoretical antecedents of the knowledge-based approach to memory development

Current mainstream psychological approaches to the study of memory evolved out of a number of broad theoretical orientations, both within psychology itself, and within the adjacent fields of cognitive science and artificial intelligence. We should not think of this theoretical development as some sort of mandatory process, as if historical forces inexorably steered research to its present state. Such a *deus ex machina* view of history is doubtlessly naive. In fact, progress in psychological theorising in the area of memory research has been rather haphazard. In many ways the field still remains fractionated, different theoretical lines are pursued contiguously, and research findings are not always adequately integrated (see Oden, 1987).

It is nevertheless possible to extract some broad theoretical trends in psychological approaches to memory and memory development, if only for expository purposes. In this section a few general trends that have influenced psychological theorising about memory development are briefly discussed.

2.2.1 Semantic memory and the representation of conceptual knowledge

A recurrent theme in psychological research is that memory constitutes an associative system (e.g., Anderson & Bower, 1973; Greeno, 1970; Howe, 1985; Raaijmakers & Shiffrin, 1981). In such a system, conceptual elements are stored by associating them with other elements in memory. We can think of this kind of system as a network with paths joining concepts associated in memory so that they can activate one another during recall. It is usually assumed that the formation of associations is based on temporal or spatial contiguity, and hence that objects, events or words that frequently co-occur in the environment become associated in memory (Howes, 1990).

Part of the appeal of an associative system as a model of memory is that it fits our everyday experience of memory behaviour. During the course of experience, we build up a conceptual representation of the world by forming connections between people, events and places, and by correlating features with objects. Sensory input usually triggers off a cascade of associations and recollections, reminding us of previous perceptions, experiences or thoughts. Thus, a pine tree may evoke childhood memories of Christmas, seeing a dog may make us think of a pet we once had, or hearing a song on the radio may suddenly conjure up an image of someone we used to know. Such examples strongly suggest that human memory works in an associative fashion.

However, human memory is more than just an associative system. Memory functions also include partitioning conceptual items into discrete categories such as animals and buildings, and organising incoming information on the basis of abstract semantic and conceptual relations in order to reduce the complexity of the world to manageable proportions. In fact, most modern conceptions of an associative memory also include an organisational component (e.g. Kohonen, 1984). In psychology, this organisational aspect is now commonly represented by means of semantic networks.

A semantic network is a kind of formalism (a directed labelled graph) used to model the connectivity, the interrelationships of conceptual items in memory. The formalism has its origin in a computer simulation developed by Quillian (1968) to model the process of natural language comprehension. The theory, and empirical application, of semantic networks were subsequently extended into mainstream psychology by inter alia Collins and Loftus (1975) and Anderson (1976; 1983). However, these subsequent models preserve the major details of Quillian's original design.

Briefly, the model operates as follows. Words or concepts are represented as nodes in a network. All the nodes are interconnected by links with variable weights attached to them, representing the strength of association between words. The hierarchical nature of the network results in an economical representational format, because nodes lower in the hierarchy can inherit the properties of their ascendants. This means that not all properties associated with words have to be explicitly represented. The system recovers the meanings associated with two or more words by finding a path connecting them through a process of 'spreading activation'. Spreading activation is actually a form of search that combines the traditional depth-first and breadth-first search techniques used in computer science. This is achieved by simultaneously traversing the network horizontally and vertically from any two specified nodes in the network to determine the shortest path between them. The resultant search process is also known as 'marker passing' (Hendler, 1988) and produces a kind of ripple-like effect that spreads associatively through the network from the point of origin.

Semantic networks have a certain intuitive appeal in that they graphically display the organisation of knowledge, and are thus somewhat more expressive than other representational schemes (e.g. predicate calculus). In these models related information is clustered or bound together by means of weighted relational links, and hierarchical relationships are shown as trees in the network. Conceptual structures such as semantic categories and schemata, as well as the associative or semantic relations among words can easily be represented in this graphic manner. This probably accounts for the popularity of such models among developmental psychologists.

The network formalism provides a way of conceptualising cognitive development in terms of changes in the organisation and relational structures of the network. It also provides a mechanism for formalising our intuitions and ideas about semantic memory, and about the way in which information is represented and processed in it. As such it has played a significant role in the development of theoretical approaches to the problem of memory development.

2.2.2 The organisational approach to memory

As already noted, human memory is an organised system and any theoretical approach to memory should reflect the organisational properties inherent in it. The central role that the concept of organisation plays in memory research can perhaps best be appreciated by considering it in relation to three important studies.

The thrust of the organisational approach to memory revolves around the unitisation or chunking hypothesis. Empirical evidence deriving from a number of different sources appeared to suggest that there are strict limitations on the human information processing capacity. In a now famous study Miller (1956) argued that a maximum number of 7 ± 2 unrelated items can be entertained concurrently in immediate memory. Clearly, however, humans are capable of dealing with more information at a time (e.g. sentences containing more than nine words) so that some mechanism obviously exists by which memory capacity can be extended. Miller advanced the hypothesis that the capacity limitations of the immediate memory span can be overcome by grouping information into chunks (i.e. by applying an organisational strategy). More specifically, he argued that chunking serves to augment the information load of each item and thus helps to break the 'informational bottleneck' (Miller, 1956, p. 313). As we shall see in the next section, in its strict form the idea of capacity limitations is no longer tenable, but it survives in slightly altered form in memory research.

Almost contemporaneously with this work on chunking, Bousfield and his colleagues (Bousfield, 1953; Bousfield, Cohen & Whitmarsh, 1958) showed that subjects are inclined to group verbal items during free recall in terms of observed relationships among the items, such as categorial, associative or acoustic similarities. The relevant finding here was that associatively or categorially (i.e. members of the same semantic category) related words generally formed clusters in the recall protocols. Because such clustering occurs even when the experimenter takes care to deliberately segregate the relevant words in the verbal lists presented for recall, Bousfield and his colleagues hypothesised that it reflects a deliberate organisational strategy on the part of the subjects.

Tulving (1962) presented evidence that people use subjective organisational schemes to structure verbal material in their memory output, even when the material consists of seemingly unrelated words. Tulving's conclusion derives from a statistical analysis which showed that the recall order of such 'unrelated items' was nonrandom, became increasingly stereotypical across successive trials and thus appeared to be subjectively determined. Under the null hypothesis one would expect the material to be recalled either in a random order, or in the order in which they are presented, but neither of these two cases obtained.

These studies spawned a whole literature concerned with the systematic investigation of organisational and grouping processes and their effect on memory performance. Emerging from these studies is a broad consensus about the role of organisation in memory processes. Some of the salient points are: (a) Level of organisation generally covaries with amount recalled, so that increases in organisation result in augmented levels of recall. (b) Organisation is primarily a strategic process that is deliberately employed to improve recall; however, grouping effects are also observed in cases where the subjects are not aware of having employed such a strategy (see Lange, 1978). (c) Organisation and grouping processes enhance recall because they exploit knowledge (i.e. semantic and associative relations) in long-term memory (see e.g. Schneider & Pressley, 1989; Pellegrino & Ingram, 1979).

Organisation is also a factor in memory development. Numerous studies report developmental differences in the way subjects organise their output in memory tasks (see e.g. Ornstein & Corsale, 1979 for a review). As a rule young children show minimal amounts of organisation when the task material consists of categories based on adult norms, but they can be trained to implement an organisational strategy on the basis of such material. Some researchers have argued that such failure to deploy organisational strategies spontaneously reflects a performance deficiency, and hence derives from an immature strategic ability (e.g. Moely, Olson, Halwes & Flavell, 1969).

However, such an interpretation is premature, because inferences about children's organisational abilities cannot really be made in the absence of any idea as to how conceptual knowledge is represented in children's memories. A possible reason for children's apparent reluctance to implement an organisational strategy is that the experimenter-defined structures in the stimulus material do not correspond to the way in which information is structured in children's memories (see e.g., Schneider & Pressley, 1989, p. 53). If so, the grouping effects actually observed in children's recall can be used to glean information about the structure and content of their semantic memories. Lange (1978) makes this point, arguing that the organisation or clustering observed in young children's recall do not reflect deliberate organisational strategies, but can be more parsimoniously attributed to the relatively automatic activation of interitem associations in the knowledge base.

It is particularly in this latter sense that the phenomenon of organisation currently commands interest among developmental researchers. The research focus has now shifted from a concern with organisation as a strategic process, to a more detailed analysis of the actual memory structures that underlie the consistent organisation sometimes observed during free recall (see Friendly, 1979). As a result of this change in focus, research on organisational and grouping factors in recall now closely intersects with research concerned with the effect of the knowledge base on memory processes.

2.2.3 The role of mental resources and automaticity in memory development

An assumption which has endured throughout much of the early development of information-processing psychology, is that short-term memory is severely limited in its information storage capacity. This assumption of a capacity-limited processing mechanism was articulated in Miller's (1956) publication, and subsequently became entrenched in memory models such as the multistore model of Atkinson and Shiffrin (1968). The basic ingredients of Atkinson and Shiffrin's model were a number of modality-specific sensory stores, a capacity-limited short-term memory system and a long-term memory where information could be kept almost indefinitely.

Short-term memory was assumed to be the locus of controlled processes such as rehearsal and organisation. These were thought to be strategic activities whose main function is to reduce the storage limitations of the short-term store. Some of these ideas about the operation of the memory system were also applied to theories of memory development. For instance, a rather compelling hypothesis at the time was that age-related differences in memory abilities could be attributed to differences in the hardware of the memory system. Much of the data on memory development could be accounted for by simply asserting that children's memory spans are more limited than those of adults, and that memory development is essentially a question of neurological maturation, a kind of 'shifting upper limit' that comes with age (see Bjorklund, 1989; Dempster, 1985).

This hypothesis is no longer considered tenable in its extreme form. The container metaphor of memory on which the multistore model is based has been shown to be problematic in the light of recent research. There are also internal contradictions associated with the model. For instance, in some cases such as pattern recognition it would seem more logical to bypass the short-term store and access long-term memory directly instead of the linear flow of information posited in the model (see Cowan, 1988). More significant, however, is evidence suggesting that short-term memory capacity can under special training undergo drastic improvements. Thus, Staszewski (1990) refers to two subjects who were able to expand their memory spans to 80 and 106 digits respectively under laboratory-training conditions. This data would seem to render the notion of a strict limitation on short-term memory rather vacuous.

Dissatisfaction with the container metaphor has led to a variety of alternative conceptions of short-term memory. Many developmental researchers have taken over the notion of working memory as elaborated by Baddeley (1986). An alternative conception holds that short-term memory and working memory are functionally distinct systems in which short-term memory remains a rather passive storage and representational system (e.g. Brainerd & Kingma, 1984). However, an increasingly popular view among psychologists is that there is no short-term store separate from long-term memory. Instead short-term memory is simply the activated portion of long-term memory (Dempster, 1985).

The capacity hypothesis still prevails in developmental psychology (see e.g. Halford, 1982), but its theoretical foundations are now rather shaky. For instance, age-related increases in digit span are sometimes invoked in support of the hypothesis, but as Chi and Ceci (1987) argue, young children take significantly longer than adults to encode digits. Encoding speed is probably related to the way the stimulus is represented in memory. Adults' greater knowledge of digits entails that digits are more elaborately represented in their knowledge bases, with more and stronger pathways leading to them so that they can be more rapidly searched and accessed during memory tasks. On this view then, the span differences observed with different age groups are simply artefacts of differences in the nature and organisation of their knowledge bases.

Some developmental theorists (e.g. Case 1985; Bjorklund, Muir-Broaddus & Schneider, 1990) posit a limited pool of mental resources available for cognitive activities. With age the amount of resources available is thought to remain the same, but repetition of cognitive tasks eventually render their execution almost automatic. This liberates resources which can now be allocated for more effortful activities (e.g. strategies such as rehearsal or organisation). The basic prediction is therefore that with practice cognitive processes become increasingly automatised, consume less effort and thus liberate mental resources for allocation to other complex meta-activities, such as strategic processes.

2.3 Towards a theoretical framework

Emerging from these research themes is a broad theoretical framework for thinking about the role of the knowledge base in early memory development. This framework is set out in Bjorklund (1987) and Bjorklund, Muir-Broaddus and Schneider (1990), but also underlies the work of other developmental researchers (e.g. Chi & Ceci, 1987; Ornstein & Naus, 1985; Gitomer & Pellegrino, 1985). Essentially the claim is that the knowledge base affects the ease with which information is encoded, processed and retrieved, with concommitant effects on memory performance (Muir-Broaddus & Bjorklund, 1990, p. 99). These researchers further posit that the effect of knowledge on memory processes can be modelled by means of a 'modified' semantic network along the lines proposed by Anderson (1976), Collins and Loftus (1975), and Norman and Rumelhart (1975).

2.3.1 Representational and processing assumptions

The general scheme adopted is as follows: The conceptual items in semantic memory are represented as sets of interconnected nodes in a network, with each item connected by means of labelled relational links to many other items in memory. Because the links are labelled they can express various kinds of relationships, such as associative (i.e. temporal or spatial contiguity), categorial (i.e taxonomic), schematic, (i.e. part-whole) and functional (i.e. causal) relations between the items in memory. In addition, each item is associated with features that characterise its semantic structure (e.g. the item *cat* is associated with the features small, furry, miaows, chases mice). Such features mediate inter-item associative processes in the sense that items become associated when it is recognised that they have features in common. The representation in the network is hierarchical, and the properties or features associated with items are nested under them. The resultant picture is a complex network of interrelationships in which clusters of items, that are strongly associated or connected on the basis of hierarchical or schematical relations, form organised substructures. This organisational component is represented in terms of spatial proximity in the network and by attaching weights to connections so that high weights are assigned to the links connecting strongly related items. For instance, a high weight would be attached to the link joining the items *bird and sparrow* because a sparrow is a prototypical bird, but a weaker weight will be assigned to the link connecting *bird* and *ostrich* because an ostrich is not a typical member of the bird category. Semantic distance is therefore captured by means of weighted links in the network.

Within this framework, the retrieval of information in memory is achieved by a process of spreading activation. The basic assumption here is that when a retrieval cue is given, when memory search processes are initiated, or when an item is primed in memory, activation spreads associatively through the network. Activation may be likened to energy in the memory system which travels outward along the paths emanating from the point of origin to some unspecified depth in the network. Items lying in the path of the spread of activation are tagged and, if their level of activation exceeds some pre-specified decision threshold, become available for recall. Activation is a resource bound process, and is subject to decay after a brief period of time (in the order of a few seconds).

The memory system itself consists of two components, a short-term store and a long-term store. The currently activated items in memory constitute the short-term store, and the unactivated portion of memory is the long-term store. The probability of activation is viewed as a function of context, inter-item associativity, the number of typical features associated with an item, and the frequency with which the item had been activated in the past (see Bjorklund, 1987).

Let us now consider some of the developmental implications which can be teased out of this framework.

2.3.2 Modelling developmental changes in memory processing

Using the theoretical framework sketched above as a basis, Bjorklund (1987) isolates a number of parameters implicated in the developmental process. These are set out below.

Memory development involves first of all item specific effects. There is a net increase in the number of items stored in memory, which can be attributed to the vocabulary growth occurring throughout the period of cognitive development. This increase in vocabulary means that the content of the knowledge base is enriched in that it becomes more detailed and articulated. As the knowledge base expands, more features are added to individual items so that they become more distinctive, and hence accessible, in memory. The accessibility of conceptual items is further augmented by repeated exposure, and thus frequent activation, during memory related processes. Frequent activation implies that the decision threshold for such items will be lowered so that they are more readily available for recall (i.e. more easily activated and introduced into the short-term store). The conjunction of these changes entails that memory related tasks are executed more effectively because items are more elaborately encoded in memory and thus easier to activate during memory functions (see Bjorklund 1987; Bjorklund, Muir-Broaddus & Schneider, 1990).

A second major result of development is changes in the relational structures of the knowledge base (i.e. between item effects). With age more connections are forged between the entries in semantic memory, and items are gradually arranged in terms of increasingly complex associative and relational structures. Semantic categories become better established and more integrated as additional features associated with the category are acquired, and as the superordinate-subordinate relations in the category are mapped out (Ornstein & Naus, 1985, p. 124). In the process the arrangement of information in the knowledge base becomes more hierarchical and better organised. In addition, the associative or relational links between items that are frequently activated together are strengthened (i.e. higher weights are assigned to these links) so that their activation threshold is lowered. Such items are thus capable of activating one another more easily. The formation of more complex relational structures entails that multiple pathways leading to items in memory are established, which facilitates access during memory tasks (Chi & Ceci, 1987). The effect of such incremental changes in the ease of activation of sets of items in memory is that highly articulated associative and categorial network structures are established that can be deployed during memory processes to aid recall (Bjorklund, 1987; Ornstein & Naus, 1985).

Fairly idiosyncratic developmental differences in both the type of relations obtaining between entries in semantic memory and the type of features associated with them may also occur (Bjorklund, 1987, p. 95). Such changes can be predicted if we assume that children's knowledge bases are more fragmented and less elaborate than adults, containing a smaller variety of typical features connected with items in memory and fewer exemplars associated with semantic categories (Chi & Ceci, 1987; Nelson & Hudson, 1988). This may lead to a number of different encoding and processing biases which will change developmentally and affect the type of features and dimensions attended to in memory tasks. Such processing biases can occur if children assign different priorities than adults to features in the featural hierarchies associated with items in memory, and have difficulty in adjusting their processing to task demands (see Bjorklund, 1987). Gibson (1971) points out in this regard that part of the developmental process resides in learning the distinctive features associated with things and events and restructuring these features (i.e. changing their priorities) so that memory and cognitive processes can be strategically adjusted to the task at hand.

The question remains how the ease with which items are activated in memory actually guides the process of memory development. Bjorklund (1987) addresses this issue by postulating that there is a limited pool of cognitive resources available for mental processing. This postulate derives from Case's (1984; 1985) idea that mental capacity or total processing space remains constant during development, but that the efficiency with which cognitive operations are executed increases with age. The argument runs as follows: Developmental changes in the representation and relational structure of items in memory result in easier access to individual items and their relations and thus in more efficient processing. This increased efficiency implies that less cognitive resources are expended in the activation of information in memory, which in turn means that more processing resources become available for other cognitive tasks. These resources can then be deployed for either the storage of information or for strategic purposes such as the implementation of memory strategies.

To recapitulate then. There are at least three ways in which the knowledge base can influence memory development. Firstly, individual items may become more accessible due to elaborative encoding and frequent activation in a variety of different contexts. As a result the level of activation required in those contexts may be reduced, facilitating retrieval operations during memory tasks. Secondly, changes in the relational structures in the knowledge base may lead to relatively effortless activation of sets of strongly interconnected items. The assumption is that highly familiar items form tightly structured associative networks containing more and stronger links among items than less familiar sets so that the activation of one member in a set may activate other members. This will result in highly organised output without the need for effortful strategies. Thirdly, the increased ease of activation of semantic relations in an elaborated knowledge base may free sufficient processing space so that more effortful mental activities such as memory strategies can be deployed during memory performance. Increased strategic mediation of memory processes will ultimately improve the efficiency with which memory tasks are executed and lead to greater control over the memory system.

2.3.3 Problematic aspects of the framework

The general theoretical framework presented here provides a coherent way of thinking about the knowledge base and its effect on memory development. Nevertheless, it does contain some ambiguities, omissions and loose ends.

Firstly, the rather vague term *item* used to denote the contents of memory fudges the issue of what exactly the units of memory are. Most knowledge base theorists write as if memory consists of crisp, symbolic entities, but there are reasons to believe that it contains instead fuzzy traces. Brainerd and Reyna (1990) present a strong argument in favour of a fuzzy-trace approach to memory development, arguing that children's memory is gist-driven, immediately sensitive to patterns in the data and that cognitive development involves a 'fuzzy-to-verbatim' shift. Fuzzy-trace theory is not subject to some of the problems confronting the more orthodox representational approaches (see e.g. Shanon, 1988) and therefore merits consideration.

Secondly, Bjorklund (1987) draws extensively from Collins and Loftus (1975), but does not discuss the problems and controversies associated with their model, and the issues surrounding semantic networks in general (see e.g. Chang, 1986; Johnson-Laird, Herrman & Chaffin, 1984; Woods, 1975). Other researchers such as Chi and Ceci (1987) and Gitomer and Pellegrino (1985) are even less explicit about the nature of the network model underlying their work. This failure to address the structural and processing aspects underlying the network formalisms used renders some of these approaches somewhat opaque, and makes detailed assessment problematic.

Thirdly, the notion of a limited pool of cognitive resources is probably the most controversial aspect of the framework. Many researchers have pointed out that the construct of 'resources' is inherently ambiguous, a kind of "theoretical soup stone" that is part of the theoretical baggage of most developmental researchers, but that is seldom adequately operationalised (Navon, 1984). The theoretical justification for the resources hypothesis derives from the dual-task methodology. The pertinent finding is that when two tasks based on different cognitive modalities (e.g. reading out aloud and tapping time with a finger) are executed concurrently, they are performed less efficiently than when they are executed independently of one another. This reduction in efficiency is generally interpreted as an indication that the tasks draw from a common pool of cognitive resources. Brainerd and Reyna (1989) have argued that the effect can be accounted for in terms of output interference (i.e. that the reduction in efficiency can be attributed to response competition) and that there is no need to invoke the notion of resources.

Still, the resources hypothesis applies across a wide spectrum of data and is now deeply entrenched in many developmental approaches. Furthermore, the hypothesis has considerable explanatory power; the idea that cognitive development is a function of the automatisation and hence less effortful performance of cognitive tasks is intuitively compelling. Therefore, as Salthouse (1990) points out, for the lack of a coherent alternative the resources hypothesis is likely to remain in vogue among developmental researchers.

Despite these limitations, the framework has been subjected to considerable empirical research. Some of this research will be examined in the next section.

2.4 Examination of knowledge base effects on memory processing

The theoretical framework set out in Section 2.3 is based on a constellation of assumptions about the representation and processing of information in memory, and about the way in which the memory system develops. This framework allows us to categorise much of the data generated during the course of research on memory development, in terms of the effects of knowledge base differences on memory performance. Some of these 'effects' and the data associated with them will be considered here.

2.4.1 The effects of task-relevant knowledge on memory performance

A basic assumption underlying the proposed framework is that detailed content knowledge is an important ingredient of an efficient memory system. The effect of prior knowledge on memory performance can be demonstrated by manipulating the amount of task-relevant knowledge available to subjects. Chi (1978) tested this prediction directly by showing that the typical age differences in memory performance can actually be reversed if material is chosen with which children are more familiar than adults. She compared the memory performance of 10-year-old children and adults on two memory tasks, namely a digit-span test and a test for memory of chess positions. An important variable in Chi's study was that all the children were expert chess players, while the adults were only moderate players. The children fared worse than the adults on the digit-span test, but outperformed the adults in the chess-related memory task. They remembered more chess positions correctly, required fewer trials to reach the learning criteria, and predicted their performance more accurately than the adults. The study thus suggests that degree and type of knowledge rather than age per se is a factor in memory performance.

Similar results were subsequently obtained by Schneider, Körkel, and Weinert (1989). In this study grade 3, grade 5, and grade 7 children were required to remember a text on soccer. The subjects could be categorised as either soccer experts or novices, and also in terms of high or low general ability (intelligence scores were collected). The results of the study showed a clear main effect of expertise, with soccer experts outperforming the novices in memory performance. In addition, low general ability experts scored better than high general ability novices on all the memory and comprehension measures used in the test.

Chi and Koeske (1983) explored the nature of the representational structures associated with a specific domain of knowledge, and also dramatically illustrated the effect of the knowledge base on memory functioning. They studied a 4½-year-old boy who had a keen interest in, and an extensive knowledge of, dinosaurs. During a preliminary test the child was found to be capable of correctly naming 40 different dinosaurs. These names were divided into two groups of equal length. The one group consisted of the names of better known dinosaurs (most typical ones). The other group was made up of names of dinosaurs with which the child was less familiar (but could nevertheless name correctly). Chi and Koeske then constructed a network representation based on an examination of the child's knowledge of the two groups (e.g. they asked him to relate what he knew of individual dinosaurs, about their habitat, physical attributes and typical behaviour, relationship to other dinosaurs, etc.). The structural relations in the network associated with the better known dinosaurs were characterised by more and stronger relational links than was the case with the group of lesser known dinosaurs. The familiar group also exhibited more cohesion in terms of hierarchical organisation than the second group. In addition the child showed superior recall for the better known group, relative to the lesser known group, during memory testing.

Other studies also reveal this general pattern of results. Chi (1985) tested the memory of a 5-year-old girl for her school classmates. The child structured her recall according to seating arrangement and produced the names of 23 children in her class. Inspection of the interitem latencies revealed that there was a briefer pause between the names of children sitting together than between the names of two children sitting in different sections of the class. There is thus reason to believe that her recall reflected a process of organised retrieval based on a well-defined category in her knowledge base.

Names of classmates constitute a highly articulated domain for young children, and have also been investigated in other studies (e.g., Bjorklund and Zeman, 1982; Bjorklund & Zeman, 1983: Bernholz, Bjorklund, McKenna & Bjorklund, 1986). Bjorklund and Zeman (1982) constructed two lists; a list of names of classmates and a list of taxonomically classifiable items, and presented them for recall to subjects belonging to different age groups (younger versus older children). The older children demonstrated elevated levels of recall and clustering relative to the younger children on the taxonomic list, but these age differerences were diminished in the case of the list of classmate names.

These studies therefore replicate Chi's results, and can also be interpreted as suggesting that children apply a form of organised retrieval during recall from highly articulated domains. However, Bernholtz *et al.* (1987) argue that this organisation is non-strategic and derives instead from relatively automatic activation of associative relations in memory. They base their conclusion on the following logic. Most children were incapable of reporting a strategy. Those who did mention a strategy (e.g. seating arrangement) generally exhibited better memory performance than those who did not, but absolute levels of recall and clustering were high for both groups. The implication is therefore that most children achieved high levels of clustering and recall without the need for strategic intervention, suggesting that recall was mainly based on automatic processes in the knowledge base.

There is thus sufficient evidence that the detailed knowledge associated with articulated domains results in elevated levels of recall in memory processes associated with such domains.

2.4.2 Item specific effects on memory processes

As previously noted, one factor that is presumed to mediate age related differences in memory performance concerns the encoding and featural representation of specific items in the knowledge base (see Bjorklund, 1987). The general assumption is that items are more elaborately encoded with age, resulting in easier activation during memory functions. The influence of item-specific factors on memory performance have now been demonstrated in a number of different ways.

Bjorklund (1987) points out that age related differences in the way specific items are encoded in the knowledge base can be expected to show up particularly in memory tasks involving the recall of unrelated items (unrelated here means 'not related in terms of established category and associative norms'). We can conjecture that young children will experience difficulty in the recall of such items, because the individual entries in their knowledge bases are less elaborately encoded and thus less distinctive than those of older children (Chechile & Richman, 1982).

This conjecture is now supported by a number of different studies (see Bjorklund, 1987). In general, there are large and reliable age differences in the level of recall of unrelated items, but little corresponding age increases in subjective organisation over trials (e.g. Ornstein, Hale & Morgan, 1977; Nelson, 1969). The fact that subjective organisation remained relatively constant with age suggests that the reduced levels of recall of the younger relative to the older subjects cannot be attributed to organisational factors per se, but probably derives instead from item-specific effects.

Studies based on sorting procedures, in which the subjects are required to sort unrelated words or pictures prior to recall, have generated the same pattern of results. Even when there are no discernible differences in the level of subjective organisation imposed on the target items, older children generally exhibit higher levels of recall than younger children (Bjorklund, Ornstein & Haig, 1977).

Item specific effects are probably also responsible for developmental differences in the speed with which verbal items are processed during cognitive tasks. Presumably such differences occur because the entries in the knowledge bases of older children are more salient (i.e. more distinctive and elaborately encoded) than those of younger children and thus easier to access. Age-related differences in speed of processing have now been documented in a broad array of studies. For instance, Rosch (1973) established on the basis of a semantic verification task that 9 to 11-year-old boys were significantly slower than adults in verifying category membership. Latency differences were 1300 ms in the case of good exemplars of the category, and increased to 1600 ms for poorer exemplars.

Ford and Keating (1981) produced similar results, showing that retrieval speed increases with age. In their study, fourth and eight graders and adults were required to perform a semantic verification task. The slope of reaction time as a function of associative ratings was calculated. The associative ratings were obtained for each subject from a large sample of items. The slopes were based on average latencies for items that are high, medium or low associates of a category, and were used to partial out encoding and response factors in calculation of the semantic verification time. Large developmental differences were found, with slopes showing a marked decrease over grades.

Item specific effects also contribute to age differences in the ability to retain and generate categorically related items during memory tasks. In a study of 2-4-year-old children, Perlmutter and Myers (1979) noted age-related increases in recall for categorised sets of items, without a comparable improvement in the organisation of the output. Also, Ceci (1980) ascribes rather low levels of recall of 4-year-olds compared to older children, to the young children's failure to generate multiple semantic features associated with conceptual items and to use such features as a means of encoding target items during memory tasks.

In large part these developmental increases in retrieval speed and semantic ability seem to be attributable to changes in the knowledge base. It seems likely that the more elaborate encoding of the items in semantic memory and reweighting of the conceptual features associated with them ensure that specific items become more salient over time, and thus easier to activate during memory functions.

2.4.3 Category typicality and its effect on memory development

The pattern of results reviewed above suggests that item-specific factors are at least partly responsible for age-related changes in the knowledge base. Within the context of a knowledge base perspective, the assumption is that individual items are more elaborately represented in the semantic memories of older than younger children, so that specific items are more distinct from one another and hence easier to retrieve. A major aspect of memory development thus probably involves a restructuring process during which the semantic relations and featural specifications associated with items in memory are enriched and conceptual structures become more elaborate and organised (see Chi, Hutchinson & Robin, 1989).

Contemporary cognitive researchers generally assume that this restructuring is a gradual and incremental process. A common assumption is that children first acquire the prototypic examples of semantic categories and only gradually learn that less typical elements are also part of the same category (see Rosch, 1973). On the basis of this assumption a typicality effect can be predicted. In other words, we can conjecture that typical members of a category (i.e. exemplars of the category) will be better represented in children's memories and will consequently be easier to activate and process during memory tasks.

There is now fairly strong empirical evidence in favour of this conjecture. For instance, White (1982) found that when preschool children were presented with sets of pictures from which to select category exemplars, they generally selected members that adults would judge to be highly typical members of the category. However, the children denied that some atypical members were members of the category (e.g. that a *butterfly* is a member of the category *animal*). This occurred even though the atypical members were familiar to them.

Rabinowitz (1984) investigated the effect of category typicality using a free recall procedure. He constructed two lists, containing either highly typical or moderately typical category members and presented them for recall to second- and fifth-grade children. For both groups, levels of recall and clustering were higher for the highly typical than for the moderately typical members. For the typical members, clustering in terms of categorical relations was high even under a condition that minimised the opportunity for deliberate strategy use by requiring the children to repeat a single word during the interstimulus intervals.

In a similar vein, Bjorklund and Bernholtz (1986) explored the effect of the knowledge base on the memory performance of good and poor readers. They hypothesised that performance would be correlated with the type of material used and that atypical category members would have a more negative impact on the memory performance of poor than on good readers. This hypothesis was supported by the results of their study. On the basis of the results obtained, they further speculated that deficiencies in verbal development and poor reading ability are reflected in a rather impoverished knowledge base in which words are sparsely represented, and which contains relatively few associative and semantic relations between words.

Frankel and Rollins (1985) tested kindergarten, fourth grade and tenth grade children with four different lists. The lists were constructed from items varying in terms of strength of association and strength of category relatedness, yielding four conditions: high relatedness and high association; high relatedness and low association; low relatedness and high association; low relatedness and low association. The two older groups of children demonstrated considerable flexibility in recall and evidenced elevated levels of recall and clustering under all conditions except the one in which both category relatedness and association were low in strength. In contrast, the young children exhibited high levels of clustering only under conditions of high interitem strength. Their study thus supports the contention of a category typicality effect by showing that exemplars (i.e. typical members) of a category are more salient than nonexemplars in the memories of young children. It further suggests that young children are not yet aware of the semantic structure of categories and that their enhanced performance with typical category members can probably be attributed to the relatively automatic activation of high interitem relations existing between such items in the knowledge base, rather than to category knowledge as such.

The implication here is that category knowledge may actually emerge from an initial associative encoding of conceptual relations. Data in support of this implication will be examined in the next section.

2.4.4 From associative and functional to categorical relationships

A fairly large cluster of studies suggests that with age semantic structures become more salient in children's memories. Drawing from such research findings, some researchers have postulated that memory development entails a shift from an associative to a more categorical encoding of conceptual relations (see Bjorklund, 1985). Associative relations between conceptual items are mainly formed as a function of the frequency of their co-occurrence in the course of experience. Such relations appear to change only minimally with age, as witnessed by the fact that ratings of the associative strength between pairs of words are fairly stable across ages (see e.g. Jacobs, 1984). In contrast, significant age differences have been found in studies involving estimates of category relatedness (Posnansky, 1978). Furthermore, some researchers report that associative priming appears to facilitate speed of identification in young as well as older children, whereas category priming is only effective for older subjects (McCauley, Weil & Sperber, 1976). On the basis of such research evidence, Lange (1978) has argued that associative relations constitute a primitive form of organisation that undergoes only minor changes during the course of memory development.

Additional support for the hypothesis of an associative to categorical shift derives from studies of sorting tasks. Thus, Bjorklund and De Marchena (1984) observed a shift in the pattern of children's grouping behaviour, which changed from a reliance on associative relations (second graders) to a predominant use of nonassociative categorical relations (seventh graders). They speculate that this change in sorting behaviour reflects underlying differences in the structure of the children's conceptual knowledge, and that associative relations are easier to activate in young children's memories. Bjorklund and De Marchena further argue that as children age, their knowledge becomes increasingly organised in terms of categorical relations, enabling them to activate such relations more easily during memory tasks.

On the basis of these results it can be conjectured that young children should demonstrate enhanced levels of memory performance for lists organised in terms of associative relations relative to lists structured in terms of categorical relations. This pattern of behaviour has now been reported in a number of studies (e.g., Schneider, 1986; Bjorklund & Jacobs, 1985). For instance, Bjorklund and Jacobs claim that the children in their study (9- and 11-year-olds) did not discriminate between sets of unassociated category items (e.g. *lion, dog*) and sets of unrelated items (e.g. *dog, car*), and that these children failed to use categorical relations as a basis for recall unless they were given explicit category prompts. In addition such prompts tended to be effective only if the items were highly associated category members. In other words, retrieval cues facilitated recall if the category items were highly associated with one another (e.g. *dog, cat*), but not if they were weakly associated members of a category (e.g. *lion, elephant*).

Likewise, Nelson (e.g. 1974; 1986) has argued in a series of studies that children's early semantic development is guided by thematic and functional rather than taxonomic or categorical relationships. On this view, when given the option young children are more inclined to associate the items *dog* and *bone* (because the typical dog likes bones) than the items *dog* and *cat* (which are related in terms of category membership). For instance, Nelson (1974) reports such a preference, claiming that function, rather than colour or form, was a preferred cue for category recognition in preschool children. Recently Nelson and Hudson (1988) contended that children are biased towards a script-like or schematic coding of their conceptual experiences. They argue that young childrens' memories are organised around schematic or script-like structures "with optional paths or conditions and variables that can fill the slots" (Nelson & Hudson, 1988, p. 163). On their account, the memory systems of pre-school children are schema-bound (i.e. tightly connected to the temporal and causal structures of familiar events), but these schemata gradually become more flexible and abstract, leading to a more category-based conceptualisation of reality.

Evidence for such a shift from a schematic/functional to a more taxonomic grouping of experiential input stems from a variety of studies. Organisational preferences for functional groupings are demonstrated by classification studies (Anglin, 1970), and complemented by nonclassification studies, such as recognition memory (Scott, Serchuk & Mundy, 1982), word association (Emerson & Gekowski, 1976) and word definitions (Denney, 1974). Although there is strong evidence that preschool children appear to be biased toward functional or schematic aspects when forming categories, they can be taught to employ taxonomic classificatory schemes as was shown in a study by Smiley and Brown (1979).

In this study preschool children were presented with a standard picture and then had to select from two alternatives the best match for the standard picture. The alternatives were either taxonomically (e.g. *needle*-PIN) or thematically (e.g. *needle*-THREAD) related to the standard picture. Initially the majority of the preschool children exhibited a preference for the thematic option, while the reverse was true for fifth-grade children and college students who also participated in the study. Smiley and Brown then trained a group of preschool children to make selections on the basis of taxonomic relationships, and reported that the children acquired such a style without any difficulty. These results of a positive effect of training on the classification style has now been replicated in a variety of studies (see Ornstein, Baker-Ward & Naus, 1988).

From this literature, the following general developmental pattern in the memory behaviour of young children can be extrapolated: Preschool children seem to exhibit a pronounced bias toward associative, and functional or schema-based aspects in their conceptualisations, whereas older children and adults rely on category-based attributes to partition the objects and events of their experience into taxonomic classes. During the early school years semantic categories become more salient for young children and they gradually acquire a conceptual style oriented towards categorical relations. However, this shift cannot be attributed to children's lack of knowledge of taxonomic groupings, because they can adjust their preferences under certain favourable instructional conditions, as shown for example by Smiley and Brown (1979).

2.4.5 Knowledge base effects on the development of memory strategies

Much of the current research on memory development seems to suggest that strategies are rather inefficiently implemented by very young children and are only likely to be observed in the context of highly articulated domains of knowledge in which the children have attained a measure of expertise. Thus, Lange (1978) and Bjorklund (1985; 1987) both argue that the early development of memory is largely non-strategic and governed by associative relations and adaptive mechanisms in the knowledge base that do not penetrate into children's consciousness.

Children are often astrategic at the beginning of recall, but during successive trials their output is increasingly likely to reflect organisational aspects. Factors such as category typicality also seem to encourage the level of organisation exhibited in their recall. For instance, Bjorklund (1988) found that fourth- and seventh-grade children were more apt to use an organisational strategy in the context of typical rather than atypical members of a category. The percentage of fourth-grade children who were classified as strategic increased from 32% at trial 1 to 65% at trial 4 for typical words, whereas the corresponding figures for atypical words were 6% and 53% respectively. Given these data, Bjorklund and his colleagues have proposed that organisational strategies have their origin in the relatively automatic activation of associative and semantic relations in the knowledge base (Bjorklund, 1985; 1987; Bjorklund & Jacobs, 1985; Bjorklund & Zeman, 1982).

A computer simulation ran by Rabinowitz and McAuley (1990) seems to support the contention that knowledge base effects are responsible for the initial elaboration of memory strategies. Using a connectionist model, they trained their simulation on three different sets of Posnansky's (1978) category generation norms, applying to second-, fourth-, and sixth-graders respectively. They then claim that, based purely on variations in the constraints imposed on the strength and types of associative links, the system settled down into a pattern of activation which produced increasing levels of clustering associated with the different group of norms used. These results were obtained in the absence of any specific organisational strategy, and thus seem to reflect properties inherent in the associative relations of the knowledge structures used.

How then are strategies acquired? Bjorklund (1985; 1987) suggests that this may occur in the following way. Initially memory retrieval is mainly guided by associative processes. Associative recall is a fairly automatic process in young children and the activation of associative relations consequently requires a minimum of mental effort. In contrast, category-based recall is more effortful in that it involves complex semantic processing, such as the use of superordinate-subordinate relations linking items together in terms of taxonomic categories. For instance, children need to know such facts as that all animals belong to the class of animate beings, that this class can be partitioned into subclasses such as domestic animals, wild animals, carnivores, reptiles and birds. As children accumulate more knowledge about the internal structure of semantic categories, they find it easier to activate category relations and begin to use them as a basis for organising their output during memory tasks. Bjorklund (1987) further speculates that very young children first become aware of categorial relations by examining the content of their own processing, and then searching their recent memory for other items having similar features. This process resembles Piaget's (1971) notion of reflective abstraction; children first perform the memory task relatively automatically, and then discover how to do it more effectively by observing regularities in their own recall output.

2.5 Some remaining issues and theoretical extensions

From the research surveyed in the previous section it is clear that developmental researchers have systematically explored a variety of factors associated with the effective deployment of the knowledge base during memory functions. A central concern in these approaches is to delineate the processes and mechanisms responsible for age-related differences in memory performance.

Much of the data generated in the context of these studies suggest that the knowledge base plays a formative role during the initial stages of memory development. The general picture that emerges is that of a representational system that becomes increasingly hierarchical, structured and detailed with age, supporting more elaborate processing and more effective utilisation of cognitive resources. There is now strong evidence that the initial development of memory is largely a function of regulatory and associative processes in the knowledge base. Yet a number of issues remain largely unaddressed.

2.5.1 The emergence of superordinate categories

One important issue revolves around the question of how subordinate and superordinate relations within semantic categories develop. Although there is evidence for a general transition from an initially associative to a more hierarchical coding of information in the knowledge base, the cognitive mechanisms underlying this shift in cognitive style have not been satisfactorily uncovered. There are also inconsistent empirical data in this regard. Some studies suggest that young children have well elaborated categorical structures (e.g., Chi & Koeske, 1983), while other researchers claim that associative relations predominate in young children's conceptual structures (e.g., Lange, 1978).

Bjorklund (1987) posits that a nascent hierarchical structure will evolve from the frequent collective activation of sets of items. This joint activation is presumed to lead to the formation of structural links between the items in the set and in stronger weighting of the relations between them vis à vis other items in memory. At an abstract level this explanation seems correct, as shown by Rabinowitz and McAuley's (1990) computer simulation in which strong interitem associations were sufficient to produce grouping based on category similarity in the output. However, we need to understand the process by which hierarchical relationships are established at a more concrete level as well. More specifically, the following questions should also be addressed: What are the chracteristics inherent in the data/memory items that facilitate the formation of hierarchical relationships? Are such hierarchies formed in a sudden or piecemeal fashion? And, how do situational factors, content knowledge and domain-specific heuristics or strategies mediate the process? (see e.g., Blewitt & Toppino, 1991; Chi & Ceci, 1987; Whitney & Kunen, 1983).

The implication of Bjorklund's abstract formulation is that cognitive structures emerge in a rather *ad hoc*, undifferentiated manner. But this seems a bit tenuous. Rather, the research data already reviewed on memory development suggest that there are fairly specific empirical and cognitive constraints on the formation of conceptual structures. One such constraint concerns the effect of category typicality on memory development. As already noted, the relationship between category type and memory organisation is emphasised in the literature. This emphasis seems to reflect an implied consensus among researchers that knowledge of the exemplars associated with a category (i.e. basically an item-specific effect) mediate the acquisition of categorical knowledge. Let us consider the logic underlying this consensus in more detail. The assumption is that children develop conceptual hierarchies by first acquiring the most representative exemplars (prototypes) of a category, because these exemplify the characteristic features of the category (e.g. typical birds fly, have wings, are two-legged, have beaks, etc.). Gradually these categories are extended as children acquire more information about the category, that is, as more interconnections between items associated with categories are formed. As the connectivity and relational structures in the knowledge base expand, children assign more compex featural specifications to categories to allow for less prototypical members (e.g. they come to accept that a penguin is also a bird although it does not fly). The boundaries of the category thus shift to include more marginal category members which are only associated with a subset of the stereotypical features.

2.5.2 The basic level of categorisation

The issue concerning the emergence of conceptual taxonomies can be approached from a slightly different angle. One way of conceiving of the process by which category exemplars are acquired is suggested by Rosch and her colleagues (e.g. Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976; Rosch & Mervis, 1975). Based on empirical research into the nature and development of natural categories, Rosch *et al.* (1976) posit that there is a specific entry point into a taxonomic hierarchy, called the basic level, and that this level is psychologically fundamental. This entry point is typically at the middle of the hierarchy, thus lacking the abstractness of superordinate terms and the finer detail associated with subordinate terms. For example, *dog* and *cat* are basic level terms while *animal* is a superordinate and *dachshund* a subordinate term. Rosch *et al.* argue that basic level terms are cognitively salient because this is the level at which categorisation is determined by overall gestalt perception (i.e. does not require analysis in terms of distinctive features). And further, that this is the highest level at which a single mental image can reflect the entire category, the level with the most commonly used label for category members, the first level named and understood by children, the first level to enter the lexicon of a language, the level at which subjects are quickest to identify category members and the highest level at which a person uses similar motor actions for interacting with category members. The gist of the argument is that basic-level categories are cognitively and linguistically salient because they maximise both within-category similarity and between-category dissimilarity, and that as a result they are the members of a category which are easiest to learn.

On this conception of category structure, we can expect that basic level terms will be cognitively salient and usually well-represented in children's memories. This expectation seems to be confirmed by the literature, because the category exemplars (i.e. typical category members) that children first acquire are mostly basic level terms (see e.g. Mervis, 1987). The implication is that children first achieve access to conceptual hierarchies in a horizontal dimension, a basic level of categorisation, and then gradually learn the vertical dimension of category structure. Much of the empirical data seems to suggest that young children have acquired a well-developed representation at a less superordinate level than adults, and thus can exhibit adultlike categorisation behaviour at a lower level. That is, the members of children's basic level categories may be strongly linked to one another, but only a few linkages may connect them at a higher, more superordinate level. Young children may know that high chair and rocker are both types of chair, but lack the knowledge that chair and lamp are types of furniture (see Chi & Ceci, 1987, p. 123). In summary then, the hypothesis is that young children first form concepts such as dogs, cats, horses and then abstract the superordinate category of animals from these basic level terms.

Precisely how this process of abstraction is achieved remains a bit of a mystery. Clearly some sort of restructuring is needed in which linkages between conceptual structures in a vertical direction are formed.

2.5.3 Domain specificity and memory processes

Whether and how a cognitive restructuring process takes place is a central concern in psychology. Some theorists (e.g. Fodor, 1975) believe that conceptual hierarchies are innately determined and that no restructuring is necessary (but only a conceptual enrichment), others posit a major and global restructuring process which encompasses the whole conceptual structure (e.g. Piaget, 1971) and still others argue that restructuring is more of a local, domain-specific process (e.g. Chi, Hutchinson & Robin, 1989).

The position adopted in this thesis is that the development of conceptual structures and in particular the superordinate and subordinate relations between categories is a function of the local structure of the domain. It depends on the internal structure of the domain and on the kind of data about the domain to which children are exposed. The hypothesis is that some categories are particularly salient to young children. This may be either because the categories have salient features associated with them (e.g. very large, very small, ferocious) or because children frequently interact with them (e.g. toys, cartoons). . Moreover, children are explicitly informed about the hierarchical relations obtaining in some categories. Thus, superordinate terms are sometimes presented to children (e.g. that a stegosaurus and a triceratops are both dinosaurs), whereas in other cases (e.g. that lamps and beds are items of furniture) the superordinate relation has to be inferred. In other words, factors associated with the linguistic and social environment can contribute to differential knowledge associated with categories and their relational structures. It is therefore reasonable to speculate that children may acquire knowledge of some 'salient' categories, and even have a primitive understanding of the hierarchical structure of such categories without this understanding necessarily transferring to other less familiar categories or domains of knowledge.

In order to test the hypothesis formulated above, we first need to operationalise the term 'salient'. This can be achieved by stipulating that in order for children to experience a category as salient, they must (a) find it easy to generate members associated with the category; (b) frequently interact with the category in their environment; and (c) demonstrate knowledge of the superordinate term joining the category members and/or at least a primitive understanding of the hierarchical relations obtaining within the category. In addition, such categories will probably have salient features associated with them (e.g. prominent dimensions such as large and small). It can then be hypothesised that children will exhibit elevated levels of recall and clustering for members of such categories relative to exemplars or typical members of other categories. The implication here is of course that the recall preference cannot be attributed to familiarity per se if category exemplars are chosen as a control (the latter can be assumed to be equally familiar terms). Rather, if such an effect obtains it can be assumed to derive from knowledge of the underlying structure associated with the salient category.

Only a few published studies have tested the effect of category saliency on recall in preschool children. A number of studies have examined the effect of single categories such as names of classmates (Bjorklund & Zeman, 1982) or dinosaurs (e.g. Chi & Koeske, 1983) on recall, but few studies have considered the effect that a list containing more than one salient category will have on recall relative to a list containing less salient categories. A study by Lindberg (1980) is based on such a hypothesis, but he selected 9-year-old children and adults. Bjorklund and Ornstein (1976) tested list saliency in young children, but their study was not published. The hypothesis that a category saliency effect can be obtained with preschool children therefore warrants empirical testing. On the basis of the foregoing analysis, the following hypotheses can now be formulated:

Hypothesis 1: A category saliency effect can be predicted in the memory performance of young children. This means that children will exhibit elevated levels of recall and clustering with salient categories relative to other familiar and highly associated items.

Hypothesis 2: Salient categories are more elaborately encoded in memory and have a hierarchical structure. The presence of a nascent hierarchical structure associated with salient categories will therefore be exhibited in the recall protocols of young children.

Hypothesis 3: What constitutes a salient category depends on factors such as exposure, motivation and interest. Categories that are salient to young children are not necessarily equally salient to adults. Different patterns of recall can therefore be expected between adults and children when child-defined salient categories are used. Specifically, adults will not demonstrate the same recall and clustering preference for such categories relative to other familiar categories.

Hypothesis 4: It is assumed that salient categories are well-represented in children's knowledge bases, and are linked by strong pathways in memory. During recall trials such categories will become increasingly easy to activate so that levels of recall will increase over trials. This increase will be higher than a corresponding increase observed with familiar and associated, but non-salient categories.

The hypotheses are ordered in that Hypothesis 1 is the primary hypothesis and the other hypotheses flow from it. It is quite possible that the hypotheses formulated here may not be supported by the data. If so, the study still has merit, because the implication is then that cognitive restructuring is a global and not a piecemeal process as postulated here.

An enduring problem in memory research is to partial out the effect of encoding and retrieval on recall. Low levels of recall can either derive from an encoding deficit or from retrieval problems. Various methods exist in the literature to segregate the effects of encoding and retrieval on recall. These methods range from requiring subjects to learn the stimuli to criterion and then testing recall after a delay, to mathematical techniques used to isolate probability parameters associated with learning and retention (see Schneider & Pressley, 1989, pp. 65-72).

The method used in this study to segregate encoding and retrieval effects is slightly unorthodox, but the logic underlying it is simple. If children's reduced levels of recall is primary attributable to encoding problems, then level of recall should remain stable across trials provided of course that the to-be-remembered (TBR) items are presented only once. Conversely, if the level of recall increases or if new TBR items (i.e. items not previously recalled) are recalled during successive trials in the absence of renewed presentation, then there is reason to believe the memory recall of children is not simply a function of an encoding problem, but also derives from a retrieval deficit.

The general finding that memory performance can improve without relearning stimuli is called hypermnesia (see e.g. Payne, 1986 for a review). The implication that can be derived from the phenomenon of hypermnesia is that there is a distinction between the availability and accessibility of information in memory. Two different functional accounts of hypermnesia have been proposed in the literature. Erdelyi (1982, 1984) has argued that hypermnesia occurs in the course of processing stimuli that are readily visualised., and that it is therefore a function of 'imaginal' encoding. His position is known as the 'imagery' account of hypermnesia. In contrast, Roediger and Challis (1989) claim that hypermnesia is related to cumulative recall, and that essentially the same gains in recall can be predicted on a single trial of longer duration than those observed on the multiple trials generally used with hypermnesia experiments.

Both accounts are compatible with the claim that category saliency plays a role in children's memory performance. Firstly, such category members tend to be concrete (thus visualisable) rather than abstract items, children frequently interact with such categories, and use them in playing and fantasising so that 'imaginal' encoding can be expected. Secondly, if we assume that children undergo developmental changes in the structure and organisation of their knowledge bases, then it also follows that ease of activating items in memory changes over time. If ease of activation increases with age, then we can predict that cumulative retrieval will affect children's recall, and hence that hypermnesia will occur. Essentially this is because cumulative search processes will heighten the accessibility of items in memory and thus facilitate recall and organisation. Therefore, on both accounts hypermnesia can be predicted with the processing of salient categories. In terms of the second account, a more specific claim is made about the reason why hypermnesia occurs. This is also the account that is preferred in this study.

The general position argued in this thesis is that age-related differences in memory performance derive in large part from the structure and organisation of information in the knowledge base. Clearly, the knowledge base can affect either the encoding or the retrieval of information in the knowledge base (see Bjorklund, 1987). The knowledge base can affect encoding because it is easier to encode information in an articulated knowledge base in which information is already elaborately represented than in one in which knowledge is not well organised.

This applies to domains of knowledge as well. In elaborately coded domains of knowledge, the highly-structured representations guide inference and facilitate the acquisition and interpretation of new knowledge (see Chi, Hutchinson & Robin, 1989). Likewise the knowledge base mediates the retrieval of information. Elaborately encoded information is easy to access during memory tasks. Given that the distinct contributions of encoding and retrieval can easily be confounded in analyses of memory behaviour, two further hypotheses are formulated. These are purely tentative hypotheses that are exploratory in nature and seek to develop a better understanding of the processes mediating recall in the memory performance of young children.

Hypothesis 5: The reduced levels of recall observed in the memory behaviour of children relative to adults is at least partly due to a retrieval deficit. As a result the recall protocols of young children will exhibit a hypermnesic effect.

Hypothesis 6: Cumulative search processes play a role in children's memory performance, so that increases in level of recall and organisation will be exhibited in children's recall, in the absence of any intervening opportunities for encoding. Furthermore, given that salient and non-salient categories are not equally accessible to memory search processes, different levels of hypermnesia can be expected with the two types of category.

Of course, hypermnesia also obtains with adults, and thus suggests a more general contrast between the availability and accessibility of information in memory (e.g. Roediger & Challis, 1989). The latter point is, however, irrelevant to the logic underlying the specific hypothesis developed here. The fact that adults also sometimes exhibit hypermnesia in memory tasks does not diminish the fact that it may indicate a retrieval deficit in the memory performance of young children. Lastly, it should be noted that hypermnesia is a highly controversial phenomenon. Some of these controversies will be addressed when the experimental results are discussed in Chapter 5.

To summarise then: The main objective of this analysis of the literature is to provide a theoretical framework in terms of which the effect of the knowledge base on memory development can be interpreted. The impact of background knowledge on age-related differences in memory performance is a factor that is not always appreciated in psychological approaches to memory. The analysis conducted here suggested that content knowledge may influence memory performance in a variety of different ways, ranging from access to specific items in memory to the use of organisational strategies in recall. From this analysis, it appeared that the mechanisms underlying the process of conceptual restructuring require further specification. It was suggested that this process may proceed on a domain-specific basis and that a category salience effect will consequently be detectable in children's memory performance. In Chapter 3 the general methodology adopted and the specific experiments used to test this postulate will be described.

Chapter 3
Methodology

The previous chapter provided an interpretive analysis of the role of the knowledge base in memory development. This analysis suggested that knowledge base effects are largely responsible for the initial development of memory abilities, and that memory performance gradually improves as children encode items more elaboratively and acquire pathways joining sets of items into increasingly articulated relational structures. One issue that remains unclear in the literature surveyed concerns the mechanisms responsible for the emergence of conceptual hierarchies in young children. Current theory suggests that such hierarchies have their origin in a restructuring process, a gradual process in which category structures are expanded and the superordinate and subordinate relations associated with typical category members become available. In this study it was further postulated that this restructuring occurs in a domain specific manner, and consequently that a category saliency effect can be expected in the memory performance of young children. More specifically, it was hypothesised that category saliency would lead to enhanced levels of both recall and organisation during memory performance. This position contrasted with the alternative view, popular among Piagetians and neoPiagetians alike, that conceptual structures undergo global restructuring, with the attendant assumption of discrete cognitive stages.

The aim of the present chapter is to describe and motivate the methodology used to test the hypotheses developed in the previous chapter. These hypotheses were tested with the aid of two different experiments, which will be discussed seperately.

3.1 Experiment 1

The objective of the first experiment was to examine the effect of category saliency on recall, and was used to generate the data necessary to test Hypotheses 1-4. The experiment employed a repeated measures design in which free recall performance on two different verbal lists by the same subjects was studied. Free recall is one of the best established laboratory procedures used in psychological research on memory, and is generally assumed to provide both a reliable and an effective means for investigating memory structures and processes (Murphy & Puff, 1982). However, some researchers such as Neisser (1987) have contended that laboratory procedures are often highly artificial and therefore lack ecological validity. Such an allegation is particularly well-founded in the case of experimental studies with young children. Children can easily become inhibited by the unfamiliar conditions associated with experimental procedures and this may affect their performance (Elliot, 1983). However, free recall procedures are still routinely used in memory research on young children (e.g. Bjorklund & Buchanan, 1989; Schneider & Sodian, 1991). There are several advantages attached to this procedure: It enables the experimenter to analyse input-output discrepancies and thus to make inferences about intervening mental processes. It also helps to control extraneous variables, which is a problem with other more ecologically oriented alternatives. And, finally, it facilitates quantitative analysis because many of the factors implicated in free recall have been isolated and can therefore be readily operationalised and measured (Murphy & Puff, 1982). These aspects contribute to the continued relevance of this procedure in contemporary memory research.

In addition, the present study has at least a certain ecological orientation in that it probes categories which are very familiar to young children. Also, the children were in general highly motivated to participate. In fact, some younger children, who were not really suitable for the study, had to be tested because they insisted that they also take part.

3.1.1 Subjects

A total of 36 subjects participated in the study. The subjects were either English or Afrikaans mother-tongue speakers, and were all sampled from a predominantly white middle-class suburban area. Three groups of 12 subjects each were used: Two groups were compiled of children attending nursery school. The one group consisted of children with a mean age of approximately 4,5 years and the other of children with a mean age of approximately 6,25 years. The first group consisted of children in the penultimate year and the second group of children in the final year of nursery school. The third group consisted of adults ranging from about 25-37 years in age. There were 7 males and 5 females in each group.

All the subjects participated voluntarily. The children were told beforehand that they would be compensated for their participation, and received a small toy. The toys were handed out after all the tests had been conducted.

3.1.2 Materials

Two categorically related lists of words were compiled. Both lists consisted of 20 words, comprising 5 items from each of 4 categories. The two lists will henceforth be referred to as L1 and L2. Memory span seldom exceeds about nine items. The use of lists in excess of this length therefore ensures that recall is mediated by long-term memory. In the context of the theoretical framework adopted in this study, the implication is therefore that the subjects are forced to draw from information previously encoded in the knowledge base (i.e. relational structures) to facilitate recall.

L1 was composed of categories which were pre-experimentally established to be salient to young children. Five nursery school children, who did not participate in the experiment, assisted with the compilation of the list. In addition, the researcher's own children (two boys, aged respectively 4 and 6 years of age at the time of testing) and their friends were observed over an extended period of time, which yielded at least an intuitive appreciation of young children's fields of interest. The categories included in L1 were *dinosaurs, ninja turtles, vehicles* and *insects*. *Dinosaurs* is generally known to be a salient category for young children, particulalrly boys (see e.g. Chi & Koeske, 1983; Gobbo & Chi, 1986; Chi, Hutchinson & Robin, 1989).

Information gleaned from the parents and the nursery school teacher confirmed that many of the children tested had an extensive knowledge of dinosaurs. They regularly watched a children's television programme (Dinoriders) featuring dinosaurs at the nursery school. Furthermore, many of them had toy dinosaurs and some had acquired books about dinosaurs. The category *ninja turtles* derives from a children's television programme. During the period when the empirical research was conducted, the programme was extremely popular among young children and had generated a whole industry attendant on it involving toys, tee-shirts, and colouring books. It had even inspired a full-length movie. The other two categories, *vehicles* and *insects*, were selected because it was found during the preparation of the material that children could easily generate items for these categories. The saliency of these categories probably derives from their distinctive features (insects are very small, vehicles are means of transport) and the fact that they are popular sources for toys (e.g. ant farms, rubber spiders, toy cars, electric trains).

The categories *dinosaurs* and *ninja turtles* conform to the three criteria for saliency set out in Section 2.5.3. Preliminary testing indicated that children found it easy to generate items from these categories, were familiar with the superordinate term joining such items, and could classify them in terms of subcategories (e.g. plant eating and meat eating dinosaurs). This suggests that these categories satisfy criteria a and c. In addition, the categories feature prominently in children's fantasy games, so that they also satisfy criterion b. These are probably the most salient catgories of the four chosen. Children also knew the superordinate name for and could generate names for the category *insects*, but items from this category occur less frequently in their fantasy or game playing (this is a subjective impression). During preliminary testing two children were slightly hesitant, and produced only a few items associated with the category *vehicles*. Nevertheless, the latter category is extremely popular as a source of toys (as a visit to any toy shop will quickly verify) and can thus be assumed to satisfy criterion b. Furthermore, two of the five children involved in the compilation of the test material exhibited fairly elaborate knowledge of especially motor vehicles (one boy generated 20 items for this category), indicating that the category is very salient for some children.

The specific items and categories included in the list are indicated below:

List 1

Dinosaurs	***Vehicles***	***Ninja turtles***	***Insects***
triceratops	*boat*	*Leonardo*	*spider*
stegosaurus	*train*	*Michelangelo*	*fly*
tyrannosaurus rex	*bicycle*	*Donatello*	*bee*
dimetrodon	*motorbike*	*Raphael*	*butterfly*
apatosaurus	*aeroplane*	*April O'Neal*	*grasshopper*

Although a spider is technically not an insect, it was included in this category because young children and laymen alike tend to associate it strongly with the category of insects (see e.g. Battig & Montague, 1969).

L2 was compiled from exemplars associated with the categories *furniture, fruit, buildings* and *farm animals*. All the items selected appeared in the uppermost set of the corresponding Battig and Montague (1969) and Hampton and Gardiner (1983) category norms. Moreover, some of the items were used in a study by Hasselhorn (1990), attesting to their 'typicality'. Still, preliminary testing did not yield evidence that any of these categories are particularly salient to young children. The children could not easily generate items for these categories, were unsure of the superordinate terms joining them, and did not appear to attach any particular importance to members of these categories when playing.

List 2

Buildings	*Furniture*	*Farm animals*	*Fruit*
house	*chair*	*pig*	*orange*
hospital	*table*	*sheep*	*apple*
school	*bed*	*horse*	*grape*
castle	*couch*	*goat*	*pear*
church	*lamp*	*cow*	*cherry*

It might be argued that L1 contains some items with which adults might be unfamiliar. However, note that four of the five items from the category *ninja turtles* are named after famous artists, and that this aspect could evidently be used by the adults to organise these items during retrieval.

3.1.3 Procedure

The subjects were tested individually. The tests were administered in a quiet room at the nursery school (the lounge), and the children were brought in by the nursery school teacher. The same experimenter conducted all the tests. The subjects were informed by the experimenter that he wanted to see how well they can remember a list of words. He further explained that he would first read the words one at a time and that they must repeat them after him. They were also informed that they would then be required to recall the words in any order they like, and that they must try to remember as many words as possible. The lists were presented either in English or in Afrikaans, depending on the language preference of the particular subject.

When it was clear that the subjects understood what was required of them the test began. The order in which the two lists were presented was counterbalanced. In addition, individual items were presented in such a way that no two items from the same category appeared contiguously. The items were presented in the format *A1,B1,C1,D1,A2,B2,C2,D2,* etc., where *A,B,C,D* represent categories. This method of presentation ensures that any clustering subsequently observed in the recall output derives from an active transformation on the part of the subject. In other words, the null hypothesis is that the material will be reproduced in the same order in the recall protocols as that in which it was presented, thus exhibiting no category clustering.

Items from one of the lists were read at a rate of about one every 4 s. Following the presentation of the last item from a list, the subjects were given a little counting task (e.g. count as quickly as you can from 2 to 7). The latter served as a buffer-clearing task and was used to control for any recency effects. The subjects were then asked to recall as many words as possible. Once again it was stressed that they could recall the words in any order. After subjects reported that they could not remember any more words, or after a ± 12 s period had elapsed during which no new words were recalled, the recall trial was terminated. The second trial then began and followed the same procedure. Three trials were performed with each list and performance on each trial was recorded seperately. Intrusions (i.e. item not belonging to the list concerned) and repetitions were also recorded. Once the trials with one of the lists had ended and before presentation of the second list began, the subjects were given a distraction task such as describing and interpreting a picture in a children's book. The task had the function of clearing their memory to prevent interference effects between the two lists. To avoid spurious variation in recall due to encoding conditions, the words in both lists were presented in the same order over all the trials.

The same procedure was used with the adult subjects, but they were seen alone in a study, and a slightly more complex arithmetic task (short multiplication problems) was given. Essentially the experiment followed standard procedure, as set out in for instance Bjorklund and Buchanan (1989) and Bjorklund (1988).

3.2 Experiment 2

This experiment was in many respects analogous to Experiment 1. It was also based on a free-recall task, but only one list of words was presented. The experiment was aimed at testing Hypotheses 5 and 6, and therefore at establishing whether young children will exhibit a hypermnesic effect in their free recall output. The design of this experiment resembles that of Paris (1978).

3.2.1 Subjects

Twenty subjects were used. They were all white, middle class children with a mean age of 5,4 years, and were either Afrikaans or English speaking. Only boys were tested, largely because the stimuli appeared to favour boys. The subjects used in this experiment had not participated in the previous experiment.

3.2.2 Materials

A single list of 20 words was compiled, consisting of four items from each of five different categories. The categories chosen were *animals, dinosaurs, insects, furniture* and *ninja turtles.* The referents of the words were all concrete objects that can readily be visualised, a factor that seems to favour hypermnesia (Erdelyi, 1982). Three of the categories (*ninja turtles, dinosaurs* and *insects)* were also used in L1, and hence can be taken to be salient. The two other categories (*animals* and *furniture*) were selected from L2 and can be regarded as non-salient. This list was made up of a mixture of salient and non-salient categories so that the effect of cumulative recall on category type (one of the goals of the experiment as noted in Hypothesis 6) could be explored. The members selected from the relevant categories are indicated below:

Dinosaurs	***Insects,***	***Furniture***	***Ninja Turtles***	***Animals***
stegosaurus	*bee*	*table*	*Raphael*	*cat*
brontosaurus	*ant*	*bed*	*Donatello*	*cow*
tyrannosaurus rex	*fly*	*couch*	*Michelangelo*	*horse*
triceratops	*grasshopper*	*chair*	*Leonardo*	*dog*

3.2.3 Procedure

As in the previous experiment, the subjects were tested individually, in a quiet location. The instructions were similar to those given in the previous experiment. The items were likewise presented verbally, one at a time at a rate of about 4 s per item, and categories were interspersed so that no two items from the same category appeared contiguously in the list presented for recall. Subjects were instructed to recall as many words as possible in any order they wish. Three trials were administered. However, the items were presented only once. A trial ended after a subject either verbally indicated that he could not remember any more words or after he was unable to recall any new items for a period of about 12 s. A new trial commenced immediately after the previous trial had ended. After each trial had terminated, the subjects were instructed to try again to remember the words presented in the list. For each subject the recall output associated with the three trials were seperately recorded. Intrusions and repetitions were also recorded.

In summary then: The two experiments were both based on a multitrial, free-recall procedure, during which categorially related verbal items were presented for recall. The data generated by these experiments, as well as the statistical analyses performed on the data, will be described in Chapter 4.

Chapter 4
Results

In the previous chapter the methodology underlying the empirical aspect of this study was explained, and two experiments designed to test Hypotheses 1-6 were described. This chapter concentrates on the analysis of the data obtained from these experiments. The primary concern of the present chapter is to establish whether the hypotheses are supported by the empirical study, and as such it will detail the results of statistical analyses performed on the experimental data. More specifically, the prediction that category knowledge affects the memory processes of young children will be examined with respect to the level of recall and clustering, and the hierarchical organisation associated with the children's memory performance on the stipulated tasks.

The analysis essentially follows the logic of the presentation of the hypotheses in Chapter 2. Amount recalled and clustering as a function of age, list and trial will be analysed first. After this, the focus will shift to the more exploratory aspects of the research in an attempt to uncover the nature of the organisational factors and retrieval processes governing the subjects' recall output. The two experiments will be considered separately.

4.1 Experiment 1

The data generated by Experiment 1 were first analysed. The analysis was directed at determining whether the recall protocols of the children exhibit a category saliency effect, thus resulting in elevated levels of recall and clustering for L1 relative to L2. In addition the structural aspects inherent in the recall protocols were explored in order to establish whether there were underlying differences in the level of organisation imposed on the two lists.

4.1.1 Recall

In an initial phase, the levels of recall for L1 and L2 by the three groups were analysed. For each subject, the number of items correctly recalled per trial was separately calculated for the two lists. Repetitions would of course artificially inflate the scores for a given subject and were omitted in the calculations; that is, if a subject repeated an item in his recall output on a specific trial, the item was scored only once for the particular subject on that trial. The means and standard deviations associated with the recall output of the three groups are shown in Table 1.

Preliminary analysis did not show a main effect of sex, nor did sex interact with any of the other variables. This factor was therefore omitted in the subsequent analyses. A factorial analysis of variance with repeated measures was then performed on the recall data The number of words recalled was analysed via a 3 (age group) x 2 (list) x 3 (trial) analysis of variance with repeated measures on the list and trial factors. To guard against Type I error, the significance level for all effects was set at alpha = 0,01 unless otherwise stated. In the case of post hoc tests, care should be taken to avoid

Type 2 errors. As a result alpha was taken at 0,05 for such tests. The mean levels of recall achieved by the three age groups for the two lists used in Experiment 1 are given in the table below:

TABLE 1
Mean levels of recall obtained for L1 and L2 by the three groups.

	List 1			List 2		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
4-year-olds:						
Mean	6,92	7,42	8,33	3,83	5,42	5,50
Standard dev	1,68	2,31	2,90	1,59	1,78	2,32
6-year-olds:						
Mean	8,25	8,25	9,50	4,67	5,58	6,41
Standard dev	2,34	2,97	2,71	1,16	1,78	1,83
Adults:						
Mean	10,75	13,50	16,58	10,83	14,92	16,83
Standard dev	4,79	3,80	3,83	3,64	3,85	2,62

Three-factor experiments with repeated measures are discussed in Winer (1971, pp. 539-559). The results yielded by the analysis is summarised in Table 2.

TABLE 2
Summary of analysis of variance performed on recall scores as yielded by Experiment 1

Source	SS	df	MS	F
Between subjects				
A (Age)	2536,083	2	1268,042	37,482
Ss w. groups:	1116,417	33	33,831	
Within subjects				
B (List)	160,167	1	160,167	38,777
AB	145,528	2	72,764	17,616
B. Ss w. groups:	136,306	33	4,130	
C (Trials)	322,028	2	161,014	53,536
AC	159,472	4	39,868	13,256
C. Ss w. groups:	198,500	66	3,008	
BC	11,861	2	5,931	2,982
ABC	0,861	4	0,215	0,108
BC. Ss w. groups:	131,278	66	1,989	
TOTAL	4918,626	215		

The analysis yielded significant main effects for age (F[2;33] = 37,482), list (F[1;33] = 38,777), and trials (F[2;66] = 53,536). There were also significant Age x List

(F[2;33] = 17,616), and Trials x Age (F[4;66] = 13,256) interactions. The List x Trials, and the Age x List x Trials interactions were not statistically significant at the chosen level. A Newman-Keuls post hoc test on the means showed that the adults recalled significantly more than the two groups of children on both lists. In addition both groups of children obtained significantly higher levels of recall on L1 than on L2. Further analysis of the trials effect revealed that all three groups obtained higher levels of recall on trial 3 than on the other two trials with both lists (Newman-Keuls, $p < 0,05$).

These results are consistent with the general prediction that the children would exhibit higher levels of recall for L1 than L2, and that the same pattern would not obtain with the adults. In addition, the prediction that recall would increase over trials is also confirmed by the data, but the increase was not restricted to L1 and affected both lists. The general pattern of these results is displayed in Figures 1, 2 and 3 in Appendix A.

4.1.2 Clustering

A second stage of the analysis focused on the amount of clustering in the recall protocols. Clustering is an index of categorial organisation because it reflects the number of times items from the same semantic category are recalled contiguously. The ratio of repetition (Bousfield, 1953) was used to compute separate clustering scores for each subjects' recall as a function of list and trial. The ratio of repetition (RR) is defined as $r/n - 1$ where r refers to the number of intracategory words recalled consecutively, and n refers to the total number of words recalled by the subject on a given trial. For example, using the categories a,b, and c, the RR yielded by an analysis of the protocol abbccacbaaa is (2+2+3)/11 = 0,6.

A number of different clustering indices exist in the literature. The ratio of repetition (RR) was chosen because it does not vary systematically with amount recalled - a problem which plagues some of the other measures (see e.g., Murphy, 1979). RR is thus generally the preferred index when significant variations in the level of recall can be expected, as in the present case where the memory performance of different age groups are investigated (see Bjorklund, 1988).

Mean levels of clustering by age, list and trials are shown in Table 3. A three-way analysis of variance with repeated measures on the list and trial factors was performed on these data. The results of the analysis are set out in Table 4. The analysis yielded significant main effects for List (F[1;33] = 24,838), and for Age (F[2;33] = 4,985) ($p < 0,02$ in the latter case). There was also a significant two-way interaction for Age x List (F[2;33] = 14,012). Neither the main effect for Trials (F[2;66] = 2,158) ($p > 0,1$), nor any of the other interactions proved statistically significant. Further analysis revealed that the two groups of children obtained significantly higher clustering scores on L1 than on L2, and that the adults clustered more on L2 than both groups of children (Newman-Keuls, $p < 0,05$). However, there were no statistically significant differences in the amount of clustering for the three age groups on L1. Mean levels of clustering as a function of age and list are graphically displayed in Figure 4 in Appendix A.

TABLE 3

Ratio of repetition index for the three age groups as a function of list type and trials

	List 1			List 2		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
4-year-olds:						
Mean	0,46	0,48	0,46	0,33	0,24	0,22
Standard dev	0,21	0,15	0,19	0,28	0,19	0,14
6-year-olds:						
Mean	0,47	0,43	0,54	0,22	0,24	0,26
Standard dev	0,17	0,13	0,15	0,20	0,19	0,14
Adults:						
Mean	0,42	0,50	0,56	0,48	0,57	0,62
Standard dev	0,24	0,24	0,23	0,24	0,24	0,23

TABLE 4

Summary of analysis of variance performed on cluster scores yielded by Experiment 1

Source	SS	df	MS	F
Between subjects				
A (Age)	1,258	2	0,629	4,985
Ss w. groups:	4,163	33	0,126	
Within subjects				
B (List)	0,873	1	0,873	24,838
AB	0,985	2	0,492	14,012
B. Ss w. groups:	1,160	33	0,035	
C (Trials)	0,091	2	0,046	2,158
AC	0,252	4	0,063	2,986
C. Ss w. groups:	1,392	66	0,021	
BC	0,023	2	0,011	0,532
ABC	0,052	4	0,013	0,610
BC. Ss w. groups:	1,404	66	0,021	
TOTAL	11,653	215		

In summary, these results support the prediction that the children would obtain higher levels of clustering on L1 relative to L2. In fact, there were no significant age-related differences in the amount of clustering on L1, but the adults clustered significantly more on L2 than the other two groups. Contrary to expectation there were no statistically significant increases in the amount of clustering with either L1 or L2 over trials.

4.1.3 Organisation

Although clustering indices such as the ratio of repetition give an indication of the amount of organisation in the recall, they are limited in that they only take strict intracategory contiguity into account and ignore the overall pattern of interitem relationships in the recall protocols. In a series of articles Friendly (1977; 1979) tried to overcome this deficiency by developing a method for inferring memory organisational processes directly from the data obtained in the multitrial free recall paradigm. The method is called proximity analysis and works by computing the distances separating all the possible combinations of items from one another, averaged over the total number of subjects and the set of recall trials, to generate a distance matrix. Johnson's (1967) cluster analysis routines (diameter or connectedness solutions) are then applied to the distance matrix in order to reveal the hierarchical structures underlying the recall output. Proximity analysis thus provides a means for extracting hierarchical relationships from the free recall data, and was used in this study to determine whether the children's recall output on L1 and L2 reveal signs of hierarchical structuring in terms of semantic categories. However, before we proceed with the analysis, the specific method adopted for calculating proximities needs to be described in more detail.

4.1.3.1 Proximity analysis

Friendly (1977) proposes the following measure of proximity: Suppose a list of L items is presented to a group of S subjects on each of T trials, then for a given subject the data consists of T sequences of items of length r_t, where r_t represents the number of words correctly recalled on trial t. Let l_{it} denote the position of item i on trial t. Then the intraserial distance between two items, i and j, which are both recalled on a given trial is given by $|l_{it} - l_{jt}|$, and the distance measure D_{ij} for the pair, is simply the average intraserial distance summed over all the trials on which both members of the pair are recalled.

This yields the equation:

$$D_{ij} = \frac{\sum_{t=1}^{T} \phi_{ijt} |l_{it} - l_{jt}|}{\sum_{t=1}^{T} \phi_{ijt}} \qquad (1)$$

In (1) above ϕijt functions as an indicator which is set to 1 if words i and j are both recalled on trial t, and to 0 otherwise. Friendly (1977, p. 200) further notes that it is more convenient to think in terms of the proximity rather than the distance between items, because proximity is directly related to the "tightness" of organisation, in that the proximity index for any two items is greater the closer they are together in recall. Furthermore, average proximity can be easily defined as list length minus average distance, yielding:

$$P_{ij} = L - D_{ij} \qquad (2)$$

where L denotes list length.

An example will help to illustrate the logic of the procedure. Suppose a subject recalls a five-item list in the order *abcde*. In this case the list length is 5, and the distance between items *ab* is 1, so that the proximity measure for items *a* and *b* on this trial is (5-1) = 4. The proximities for each possible pair of items in the protocol is obtained in the same way, and then averaged over trials.

Pellegrino and Hubert (1982) advocate proximity analysis as a general procedure for exploring memory structure, and it has been shown to be responsive to the saliency of categorical relations by Friendly, Ornstein and Bjorklund (1976). However, the procedure has certain disadvantages when applied to the analysis of the recall protocols of young children. First of all, taking list length as a constant means that two items occurring in close proximity in a recall output which consists of only a few words will receive a rather low proximity value (this is because in (2) proximity is expressed as a function of total list length and not in terms of the list actually recalled). This aspect poses a problem when dealing with young children, because they tend to produce rather short lists during recall. Taking list length as the length of the list presented for recall thus has the effect of biasing the proximity values obtained to those few cases in which longer sequences of items are remembered. The problem can be resolved by calculating proximities as a function of the length of the list (i.e. number of items) actually recalled by a given subject on a given trial. Let us denote this length as l_t. An advantage of using list length in the latter way is that the effect of intrusions and repetitions (which increase list length) is taken into account, whereas they are ignored when L is adopted.

The second problem is more severe. In terms of Friendly's (1977) procedure, proximities are summed over trials and divided by the number of times any two given items are remembered together. Suppose now two items appear only once, and on that occasion in adjacent positions in the recall output of a subject. These items would receive the same proximity rating as two items which occur contiguously over all trials (a result which is clearly counter-intuitive). The problem here is that the procedure does not take frequency into account. Friendly (1977, p. 200) seems to be aware of this problem and has suggested that a threshold value should be set so that any item remembered less often than this value can be assigned a zero proximity rating. Friendly's solution is however rather ad hoc.

Bearing these issues in mind, let us now proceed to derive a proximity index for analysis of the recall protocols yielded by Experiment 1. To simplify the notation, the intertrial distance between items i and j on trial t, which is just the difference in their positions in the protocol for that trial, is denoted by d_{ijt}. Let S denote the number of subjects, and T the total number of trials for a particular age group. As no distinction between the protocols of different subjects is required at this point, the total number of trials (the maximum value that t can receive) is taken to be ST. The proximity of items i and j on trial t is defined as $P_{ijt} = l_t - d_{ijt}$. If either or both of items i or j are not recalled, d_{ijt} is put equal to l_t, so that P_{ijt} is zero. This is equivalent to Friendly's reasoning. The average proximity of items i and j (over all trials and subjects) is

$$p_{ij} = \sum_t \frac{p_{ijt}}{ST} \tag{3}$$

A slightly more sophisticated measure can be obtained by using a relative distance measure, namely distance divided by protocol length. The corresponding relative proximity on trial t then becomes:

$$r_{ij} = \frac{1}{ST}\sum_t r_{ijt} = \frac{1}{ST}\sum_t \left\{1-\left(\frac{d_{ijt}}{l_t}\right)\right\} \tag{4}$$

Note that r_{ij} takes on values between 0 and 1 only, which is convenient. Its maximum value in practice is however limited by the length of the protocol: 0,5 for only 2 items recalled, while 1,0 is approached only for extremely large protocols.

Consider now proximity measures that this index yields for a broad range of intraserial distances between a pair of items i and j, and for different protocol lengths.

Trials	*Protocol length*	*Position of i and j*	p_{ij}	r_{ij}
1	*2*	*adjacent*	*1*	*0,5*
1	*2*	*i and/or j absent*	*0*	*0*
1	*10*	*adjacent*	*9*	*0,9*
1	*10*	*at extremes*	*1*	*0,1*
1	*10*	*i and/or j absent*	*0*	*0*
5	*10*	*adjacent once, rest absent*	*1,8*	*0,18*
5	*10*	*adjacent 5 times*	*9*	*0,9*
1	*100*	*adjacent*	*99*	*0,99*

As these examples show the procedure successfully accounts for frequency in that r_{ij} grows with the size of the protocol and the number of times items are recalled in close proximity. It thus enables us to overcome the limitations associated with Friendly's (1977) index. The index was consequently used to analyse the recall data yielded by the three groups of subjects on L1 and L2.

4.1.3.2 Hierarchical clustering solutions for the proximity data

A computer program was written to calculate proximities on the basis of Equation (4) separately for L1 and L2, and for the different recall protocols. The resultant proximities were entered into a diagonal matrix. The matrices obtained for the different age groups on L1 and L2 are shown in Tables 5-10 in Appendix B. As suggested by Friendly (1979), a hierarchical cluster analysis using Johnson's (1967) diameter routine, also known as the complete linkage method (see e.g., Krippendorff, 1980), was performed on the matrices. Figures 5-10 in Appendix A show the different clustering solutions obtained with the different age groups on L1 and L2.

In terms of the prediction formulated in Hypothesis 2, salient categories are associated with a higher degree of hierarchical structure than non-salient categories. Consider now the different hierarchical clustering solutions obtained on the basis of the analysis of proximities.

For the 4-year-old group only a limited degree of hierarchical structuring in terms of the given semantic categories can be observed. The solutions obtained for the two lists differ, however, in the cohesiveness of the structures. In the case of L1, four members of the category *ninja turtles* form a cohesive structure, and are merged at the highest proximity values (0,20, 0,24 and 0,19) in the hierarchy. Two pairs are found for the category *dinosaurs*, with proximity values 0,08 (*stegosaurus* and *dimetrodon*) and 0,13 (*triceratops* and *tyrannosaurus rex*) respectively. Items associated with the categories *vehicles* and *insects* did not form distinctive categorial groupings but were mixed in the hierarchy. In the case of L2, the highest proximity value (0,24) is obtained for *lamp* and *cherry*, which are not members of the same category. Items from the category *buildings* formed a single pair (*hospital* and *castle*) merged at a proximity of 0,15, and two members (*chair* and *couch*) from the category *furniture* were paired at a proximity value of 0,13. In general the clustering solution obtained for L2 appears less cohesive than the one pertaining to L1.

With regard to the 6-year-olds, there are marked differences in the type of groupings underlying the hierarchical clustering solutions obtained for the two lists. In the case of L1, four members of the category *dinosaurs* are subsumed under a single hierarchical structure, merged at proximity values of 0,25, 0,20, and 0,12. Three members of the category *ninja turtles* are also included in a single hierarchy, with proximity values of 0,27 and 0,11 at the branching nodes of the tree structure joining these items. Two other items (*Leonardo* and *Michelangelo*) from the same category are merged at a proximity of 0,34. There is also a single pair (*fly* and *bee*) for the category *insects* merged at a proximity value of 0,23. These groupings are fairly cohesive and show some evidence of clustering on the basis of the given semantic categories. In contrast the semantic structures underlying the clustering solution obtained for L2 are much less cohesive. In fact, no clear categorial groupings can be discerned in the cluster solution yielded by the proximity data obtained from these recall protocols. There are thus very clear differences in the level of categorial clustering yielded by the hierarchical cluster analysis of the L1 and L2 proximity data associated with this group.

The hierarchical clustering solutions obtained for the adults on L1 as well as L2 represent cohesive category structures. In the case of L1, three items (*Michelangelo*, *Donatello* and *Raphael*) from the category *ninja turtles* are merged at proximity values of 0,49 and 0,39. There are also three pairs of categorially related items. One pair from the category *dinosaurs* (*tyrannosaurus rex* and *stegosaurus*) merged at a proximity of 0,32; one from the category *vehicles* (*bicycle* and *motorcycle*) joined at a proximity of 0,39, and one pair associated with the category *insects* (*spider* and *butterfly*) merged at a proximity of 0,29 in the hierarchy. The tree diagram obtained for L2 from the hierarchical clustering routine exhibits more distinctive, and cohesive, category structures. The largest proximity values are obtained for this protocol. The proximities range from 0,0 to 1,0 in this cluster solution, whereas they are restricted to the range of either -0,5 and 0,5 or 0,0 and 0,5 in the solutions found for the other protcols. All five items from the category *furniture* are subsumed under a single hierarchy, with proximities of 0,53, 0,43, 0,40 and 0,28. Five items from the category *fruit* are also joined together in the tree diagram at proximities of 0,65, 0,56, 0,53, and 0,43. In addition, three items from each of the categories *animals* (joined at proximities of 0,40 and 0,25), and *buildings* (merged at a proximity of 0,42) form clusters in the tree diagram. The remaining items from these categories are merged in two pairs. The items *pig* and *horse* from the category *animals* are joined at a proximity of 0,48 and the items *school* and *hospital* from the category *buildings* are merged at a proximity of 0,40. There are no non-categorial groupings in the hierarchical solution obtained for the proximity data associated with this protocol.

Cluster analysis has been described as a heuristic rather than a truly mathematical technique (Alt, 1989). In fact, a general problem with cluster analysis is that it always produces clusters, even when there are no natural groupings in the data (see Alt, 1989; Chi & Ceci, 1987). The results of the hierarchical cluster analysis performed on the proximity data described above should therefore be interpreted with caution. Still, the cluster solutions were analysed in relation to the natural category groupings, and these predetermined categorial groupings functioned as a 'check' against which the validity of the clusters obtained could be evaluated. Given this proviso, it can be argued that the results of the cluster analyses yield support for Hypothesis 2. The clustering solutions obtained from the proximity data of children's L1 protocols were more cohesive and associated with a more apparent hierarchical structuring of the category items than those obtained from the L2 protocols. On the other hand, directly opposite results were obtained for the adults, suggesting that age-related category knowledge was responsible for differences in the pattern of recall associated with the two lists.

4.2 Experiment 2

The second experiment constitutes a logical extension of the first experiment and attempts to explore some aspects not adequately covered by Experiment 1. More specifically, the extent to which encoding and retrieval processes mediated the children's recall is largely unresolved. In addition, the development of memory organisation over trials also needs further investigation, particularly in the light of the negative main effect for trials obtained with the analysis of clustering in Experiment 1.

4.2.1 Evidence for hypermnesia

In the first stage of the analysis the aim was to establish whether there was any increase in the amount of recall over trials. The number of items correctly recalled by each subject per trial was calculated, and these results were then analysed via a 3 (trials) x 5 (categories) analysis of variance with repeated measures on both factors. The mean level of recall per category and per trial is given in Table 11, and also shown in Figure 11 in Appendix A. The results of the analysis of variance are set out in Table 12.

With alpha set at 0,01, the analysis yielded significant main effects for trials (F[2;38] = 5,983) and for category (F[4;76] = 15,329). The Trials x Category interaction was not significant. A Newman-Keuls post hoc test on the means revealed that the subjects achieved significantly higher levels of recall on the third trial than on the other two trials. In addition, they recalled significantly more items from the categories *ninja turtles* and *dinosaurs* than from the other three categories across all three trials (Newman-Keuls, $p < 0{,}05$).

TABLE 11

Mean levels of recall expressed as a function of category type and trial for Experiment 2

Category:	Animals	Insects	Furniture	Dinosaurs	Ninja turtles
Trial 1					
Mean	0,75	1,20	0,85	2,20	1,91
Standard dev	0,91	0,95	1,18	1,54	1,33
Trial 2					
Mean	0,71	1,12	0,63	2.10	2,05
Standard dev	0,80	0,97	0,75	1,77	0,95
Trial 3					
Mean	1,05	1,11	0,75	2,65	2,42
Standard dev	0,95	0,91	0,85	1,42	0,94

The results of the analysis of variance performed on the relevant data are indicated in Table 12 below.

TABLE 12

Summary of analysis of variance performed on the recall data yielded by Experiment 2

Source	SS	df	MS	F
Within subjects				
A (Trial)	4,247	2	2,123	5,983
A. Ss w. groups:	13,487	38	0,355	
B (Category)	131,220	4	32,805	15,329
B. Ss w. groups:	162,647	76	2,140	
AB	4,020	8	0,503	0,632
AB. Ss w. groups:	120,913	152	0,795	
TOTAL	436,534	280		

The fact that the subjects achieved higher levels of recall on trial 3 than on the other two trials attests to an hypermnesic effect. Further analysis showed that the subjects recalled a total of 45 words on trials 2 and 3 which were not recalled on trial 1. These new items accounted for 27,8% of the total number of words recalled, but did not outweigh the number of items forgotten over the trials (47). The hypermnesia was a general effect and not limited to only a few subjects. In fact, nineteen of the twenty subjects recalled one or more new words over the trials. The hypermnesic effect embraced all the categories. The number of new words gained, as well as the number of words lost (i.e. forgotten) are indicated in Table 13.

TABLE 13

Number of items gained on trials 2 and 3, with items lost indicated in brackets

	Trial 2	Trial 3
Animals	2(5)	6(0)
Insects	3(5)	5(3)
Furniture	3(2)	4(2)
Ninja turtles	9(11)	1(2)
Dinosaurs	8(15)	4(2)

As shown in the table, a fairly large number of items were lost on trial 2, but this number decreased on trial 3. Although the number of items lost outweighed the number of items gained, most of the items lost on trial 2 were recovered on trial 3, so that there was still a nett increase over trials in the total number of items recalled. The highest level of hypermnesia occurred for the categories *ninja turtles* and *dinosaur.* The level of hypermnesia was strongest during trial 2 for these categories, whereas it increased from trial 2 to trial 3 for the other three categories. These results suggests that there were underlying differences in the accessibility of the categories in the children's memory, and that the categories *ninja turtles* and *dinosaurs* were more susceptible to memory search processes than the other categories (which took longer to access).

The novel items gained over trials fell into two basic classes. Items were either added incrementally on successive trials to a category already recalled on a previous trial, or a 'new' category was added to a protocol (i.e. a category was added which had not featured in the particular protocol on previous trials). Analysis of the data revealed that 67% (30 items) of the items gained over trials consisted in the addition of novel categories. Of the items added incrementally to existing categories, 80% (12 items) were from the two 'salient' categories *dinosaurs* and *ninja turtles*, whereas the majority, 60% (18 items), of those gained by the addition of novel categories belonged to the other three categories.

4.2.2 Development of organisation over trials

Given that levels of recall increased over trials, the question naturally arises as to whether the level of organisation associated with recall protocols showed a similar increase over trials. To investigate this possibility, a clustering score based on the ratio of repetition (as described in Section 4.1.2) was computed for each subject on each trial. The mean levels of clustering associated with the three trials are shown in Table 14 below and are graphically displayed in Figure 12 in Appendix A.

TABLE 14

Ratio of repetition index for the three age groups as a function of list type and trials

	Trial 1	Trial 2	Trial 3
Cluster indices:			
Mean	0,50	0,49	0,58
Standard dev	0,16	0,16	0,15

A one way analysis of variance with repeated measures on the trial (3) factor was performed on these data. The results of the analysis are shown in Table 15.

TABLE 15

Summary of analysis of variance performed on the cluster indices yielded by Experiment 2

Source	SS	df	MS	F
Within subjects				
A (Trial)	0,094	2	0,047	4,383
A. Ss w. groups:	0,427	38	0,011	
TOTAL	0,521	40		

The analysis yielded a main effect for trials ($F\,[2;38] = 4{,}383$), which was significant at $p < 0{,}02$. A Newman-Keuls post hoc test on the means showed that the level of clustering was significantly higher on the third trial than on the other two trials.

The results of this experiment therefore show that the general improvement in recall observed over the trials, was associated with an increase in the level of clustering imposed on the material to be remembered. These results are consistent with the prediction that an hypermnesic effect would be observed with the children's memory performance on this task. The fact that the children's memory performance improved over trials seems to suggest that cumulative search processes increased the accessibility of the information in memory. Children's reduced levels of memory performance relative to adults can therefore not be exclusively attributed to encoding deficits, retrieval processes and problems in gaining access to the information encoded in memory evidently play a role as well. In addition the differential patterns of recall associated with the different semantic categories provides converging evidence for the general prediction that category saliency has an effect on young children's performance on memory tasks. In this experiment significant intralist differences in the level of recall associated with the given semantic categories were found. This finding extends and provides additional confirmation for the prediction that interlist differences between salient and non-salient categories can be expected in children's memory performance.

The implications of these results in the light of the theoretical framework set out in Chapter 2, will be discussed in Chapter 5.

Chapter 5

Discussion

Many studies in psychology either ignore or underestimate the effect of content knowledge on memory performance. It is therefore important to develop a systematic approach to the role of the knowledge base in age-related memory changes, and to sketch a theoretical framework in terms of which the interplay between knowledge and memory processes can be understood. In this dissertation an attempt was made to contribute to such a research goal by exploring the effects of the knowledge base on children's memory performance, and by addressing in particular the issue of how conceptual taxonomies emerge in children's long-term memory.

It is often assumed that memory development consists in the acquisition and refinement of memory strategies such as rehearsal and organisation (see e.g. Ornstein, Baker-Ward & Naus, 1988), but an awareness of the hierarchical nature of conceptual structures is clearly an important precursor to the development of a strategic approach to memory tasks. Such knowledge logically precedes the development of organisational strategies, because children first need to develop an awareness of conceptual taxonomies before they can apply this knowledge strategically during the execution of memory tasks.

The study focused on the process by which children acquire categorial knowledge, that is, knowledge about the hierarchical structure of conceptual categories. More specifically, it was postulated that conceptual hierarchies develop in terms of local structures, that they are acquired on a domain-specific rather than global basis (i.e. permeating the whole knowledge base as predicted by Piagetian theory), and consequently that a category saliency effect can be expected in the memory performance of young children. Essentially the claim was that children will exhibit elevated levels of performance on memory tasks drawing from highly articulated domains of knowledge, while reduced levels of performance will be observed on tasks associated with less elaborated domains of knowledge. The empirical part of the study was intended to test the hypothesis that differential patterns of recall can be expected with salient and non-salient categories, because they reflect differences in the knowledge available about underlying categorial structure. It was assumed that this knowledge would translate into differences in memory performance, both in the level of recall and in the amount of organisation imposed on the material to be remembered.

Let us now attempt to place the results of the analyses reported in the previous chapter within this broader theoretical context.

5.1 The effect of content knowledge on recall and clustering

The basic hypothesis that different levels of recall and organisation can be expected with salient and non-salient categories was confirmed by the study. The children achieved higher levels of recall on L1 (i.e. the categories operationally defined as salient), than on L2 (i.e. the non-salient categories). Moreover the adults obtained slightly higher scores on L2 than on L1, thus showing that the children's recall protocols were not simply an artefact of the particular experimental procedure employed. Rather these results suggest that age-related differences in susceptibility to the material contained in the two lists were responsible for the different patterns of recall by the adults and children on this task. More specifically, the results are consistent with our conjecture (formulated as Hypothesis 1) that the categories included in L1 are more elaborately encoded in the children's knowledge bases than those in L2, and would therefore be easier to activate during recall.

It was further predicted that the children would exhibit elevated levels of clustering on L1 relative to L2. This prediction was also confirmed. In fact the children achieved very low levels of clustering on L2, as measured by the ratio of repetition, whereas their clustering on L1 was comparable to that of the adults. These results suggest that the categories in L1 are highly salient for the children, and are more hierarchically encoded in their knowledge bases than those from L2. Moreover, the effect of the knowledge base on the children's memory performance is clearly perceptible in the results of the cluster analysis performed on the proximity data. The cluster analysis yields support for Hypothesis 2 by showing that the recall protocols of the children on L2 were associated with very little hierarchical grouping, whereas an emergent hierarchical structure could be discerned in their recall of the items in L1. It further indicates developmental patterns in children's organisation of their recall output, in that the hierarchical cluster solutions yielded slightly more pronounced categorial groupings for the proximity data derived from the 6-year-olds' L1 recall protocols than for those obtained from the 4-year olds on the same list.

On the other hand, the almost total absence of any categorial structure in the children's recall output of L2 suggests that they relied on item-specific, serial search processes to recall the items from this list. The children may have been forced to resort to a serial search strategy because the pathways connecting the items from these categories in their memories were not strong enough to elicit interitem associations during recall.

5.2 The emergence of an organisational strategy

The results of the analyses performed in the previous chapter reveal a correlation between amount of clustering and recall. High clustering scores were associated with high levels of recall - an effect which held for the adults as well as the children. As already noted, the relatively high level of clustering observed in the children's L1 recall protocols suggests that these categories are linked by strong interitem associations, and thus that they have a fairly cohesive structure in the children's memories. The children's elevated levels of performance with these categories, relative to those in L2, appear to be attributable to the detailed conceptual information available about them. However, it is not clear whether the clustering observed in the children's L1 protocols derives from intentional factors, that is, from the deliberate deployment of an organisational strategy. In fact, some researchers (e.g. Lange, 1978; Bjorklund, 1985) have argued that clustering may result from fairly automatic activation of strong interitem associations in the knowledge base, and need not point to any deliberate organisational plan on the part of children.

Part of the difficulty in determining whether children's memory performance is strategic lies in the lack of a clear definition of what exactly constitutes a memory strategy. The term is seldom adequately operationalised in the literature, and has at best a rather fuzzy sense (see Bjorklund & Buchanan, 1989). In the context of memory research, it generally denotes a process that is at least partly amenable to cognitive control. In addition it is often held that strategies are planful, goal-directed operations specifically aimed at improving memory performance (see e.g. Bjorklund & Harnishfeger, 1990). Many developmental researchers apparently assume that memory performance is initially based on automatic processes, and that during cognitive development there is a transition from unconscious or automatic to strategic or consciously controlled behaviour in the execution of memory tasks. However, it is unclear whether this transition is sudden or gradual, and indeed what factors govern it. Still, the general idea is that automatic and strategic processes are different, and incompatible aspects of memory performance (Lange, 1978; Bjorklund, 1985).

The assumption that the automatic and strategic aspects of memory functioning derive from dichotomous components may be too extreme. Within an information processing perspective, strategies are simply task appropriate behaviours intended to maximise performance (see Howe & O'Sullivan, 1990, p. 132). In such a framework memory strategies are sets of processes, involving both automatic and strategic (i.e. controlled) aspects, which govern the execution of essential memory functions such as encoding, storage, search and retrieval. The implication here is that the boundary between automatic and strategic processes may be quite fluid, so that we should rather think of memory performance as a continuum ranging from a predominantly automatic to an increasingly strategic set of cognitive processes. The postulation of a rigid division between strategic and non-strategic behaviour, on the assumption that the existence of automatic processes necessarily precludes any strategic component (or vice versa), may in fact obscure the emergent properties inherent in the early use of memory strategies.

The position favoured in the present study is that the knowledge system is really an active and dynamic processing system in and of itself, and that the initial development of the knowledge base constitutes a kind of enabling condition, a necessary preparatory stage eventually leading to the emergence of a certain degree of strategic control over memory functions. On the whole, the data generated from the two experiments are consistent with this general theoretical orientation. The marked differences observed in the level of organisation imposed on the categories in L1 and L2 in Experiment 1, as well as the intracategory differences found in Experiment 2, show that there are differences both in the way categories are encoded in the children's knowledge bases, and in the efficiency with which they are processed.

Furthermore, the different levels of hierarchical structuring yielded by the cluster analysis of the proximity data obtained from the L1 and L2 protocols, indicate under what conditions such strategic abilities may arise. Given the general pattern of results associated with these data, it seems reasonable to suppose that memory strategies will be manifested initially in the context of highly articulated knowledge structures. In fact, the organisation (i.e. transformation of the input prior to output) observed in the children's L1 protocols seems at the very least to be indicative of an early strategic orientation to memory tasks.

5.3 Improvement in recall over trials

It was further postulated that there would be an increase in the amount of recall and clustering over trials and that in the case of the children, the increase would be greater for L1 than for L2. This hypothesis derived from the assumption that the categories in L1 are elaborately represented in the children's knowledge bases, and that access to them would be facilitated as a result of repeated activation, thus producing a net increase in the level of recall over trials. For the same reason, it was argued that there would also be an increase in the level of clustering for the L1 protocols over trials. Furthermore, because the L2 categories were considered to be less elaborately represented in the children's knowledge bases than those from L1, it was expected that the increase in the level of recall and clustering would be smaller for L2 than for L1.

These hypotheses were not confirmed by the study. The first experiment yielded no statistically significant difference in the rate with which the level of recall associated with the two lists increased over trials. It also yielded no significant increase in the amount of clustering as a function of trials. In contrast, a significant difference both in the amount of clustering and in the levels of recall between the first two and the third trial, were observed in Experiment 2.

The analysis of variance performed on the children's recall data yielded by Experiment 1, produced a main effect for trials with regard to level of recall, but not clustering. As Table 3 shows, the 6-year-olds clustered slightly more on trial 3 than on trial 2, but their clustering actually decreased from trial 1 to trial 2. In addition, the 4-year-olds attained the same levels of clustering on trials 1 and 3, and thus failed to exhibit any nett increase in clustering after three trials. Evidently then the notion that an increase can be expected in clustering over trials proved misguided. Instead, levels of clustering fluctuated and only increased slightly for the older children. Furthermore, Table 1 (also Figures 2 and 3 in Appendix A) indicates only a moderate increase in the mean level of recall produced by the 4-year-olds over the three trials. In the case of the 6-year-olds there was no distinction between the mean levels of recall achieved on trials 1 and 2 for this list. Given that an interaction between the trials and list factors was predicted, the pattern of results yielded by the experiment is clearly problematic and needs to be interpreted

Note that the theoretical position adopted in this study is that levels of recall and clustering are mediated by a process of activation spreading over a network of semantic relations encoded in the knowledge base. Given this framework, the problem that needs to be addressed concerns the failure to find a marked increase in the children's ability to activate the L1 items over trials.

Consider now the following factors: Firstly, the data yielded by Experiment 2 suggest that different patterns of activation are associated with categories, and that some categories are activated more easily than others. Secondly, even though the categories in L1 were taken to be salient, they are not equally salient as shown by the cluster analysis which yielded different degrees of hierarchical grouping for the children's recall protocols associated with the categories in this list. Thirdly, it seems reasonable to postulate that any increase in activation will be curtailed by available resources (clearly activation must have some or other upper bound).

Given these factors, we can conjecture that the exemplars of the different categories in L1 may have had an inhibitory effect on one another during recall. The reasoning here is as follows: Suppose that activation is distributed over the members of the different categories in L1, that only a limited pool of cognitive resources is available for recall, and that activation decays rapidly (as posited in Section 2.3). Under these circumstances, the different categories may have competed for output so that, due to capacity limitations in the production system, not all the items activated on a given trial would necessarily be recalled on that trial. Think of this as a race in which the to-be-rememebered (TBR) items compete for recall. Items which 'lose the race' on any particular trial are tagged (a residual level of activation remains) and these items are recalled first on subsequent trials, because the residual level of activation plus the new activation heightens their accessibility relative to other items.

Alternatively stated, on successive trials the children may have tried to compensate for their failure to produce some TBR items on previous trials by directing most of their efforts at recalling such items. This entails that much of the practice effect associated with repeated activation would not carry over to the TBR items already recalled, because resources are largely expended on remembering 'new' TBR items. In this way a source of variability in recall output could have been introduced which might have lowered the effect of an increase in activation over trials on recall.

The obvious retort to the explanation set out above is that activation did in fact increase in Experiment 2 as witnessed by the heightened levels of clustering and recall that the subjects attained on the third trial in this experiment relative to the other two trials. However, note that both salient and non-salient categories were used in Experiment 2 so that the likelihood of response competition between members of the salient categories was reduced simply because there were fewer salient items competing for output than in Experiment 1.

At least some aspects of the data are consistent with the explanation presented above. An analysis of the data obtained from the second experiment revealed a high forgetting rate in the second trial, but most of the TBR items forgotten in the second trial were recovered by the third trial. This is exactly the type of data one would expect if response competition played a role in the children's recall. If the TBR items vied for output, and if the children either consciously or unconsciously tried to compensate for this effect, fairly high levels of forgetting (to make place for the recall of new TBR items) can be predicted. Still, although this explanation fits the data, it is rather speculative and requires further elaboration and testing before it can be put forward as a coherent proposal.

5.4 The hypermnesic effect

The rationale for conducting the test for hypermnesia was twofold. Firstly, the test was intended to show that the relatively low levels of recall typically associated with children's performance on memory tasks are not attributable solely to an encoding deficit on their part, but derive, at least in part, from inefficient retrieval processes. In other words, it was posited that the children's reduced levels of performance relative to the adults are partly due to a retrieval deficit, a difficulty in gaining access to the information stored in memory. The idea here was that an hypermnesic effect would show that information which had been encoded was not immediately accessible, but was recovered over time, possibly as a result of cumulative search processes.

The test for hypermnesia was further intended to explore the organisational aspects associated with children's memory search processes. In the typical memory paradigm stimuli are presented anew prior to each retrieval session so that encoding and retrieval factors are difficult to disentangle. In the second experiment, encoding and retrieval factors were segregated, in that a single opportunity for encoding, and a number of successive opportunities for retrieval were investigated. The emphasis was thus placed on the effect of cumulative retrieval processes on clustering and recall.

The experiment yielded a main effect of trials both in the analysis of level of recall, and in the examination of the level of organisation associated with the children's protocols. The experiment thus confirmed the hypothesis that children's impaired performance on memory tasks are at least partly due to inefficient retrieval processes. This conclusion follows logically because improvements were observed in the children's performance without any intervening opportunities for encoding. Furthermore, the fact that such improvements occurred over time attests to the dynamic character of the knowledge base, and provides additional support for the previous argument (Section 5.2) concerning the adaptive mechanisms inherent in the knowledge system itself. The experiment also yielded intracategory differences in recall. This finding is compatible with Hypothesis 1, and logically extends the thesis that interlist differences, attributable to a category saliency effect, will be found in children's memory performance, by showing that this effect also produces intralist differences in recall.

The phenomenon of hypermnesia is quite robust, and has been repeatedly demonstrated in psychological research (see e.g. Payne, 1986). In the recent literature, researchers have focused primarily on functional accounts of the hypermnesic effect in an attempt to clarify the conditions necessary for its occurrence (e.g. Klein, Loftus, Kihlstrom & Aseron, 1989). Much less is known about the cognitive mechanisms underlying hypermnesia, and many researchers still draw from Ballard (1913) when explaining hypermnesia (see Roediger & Challis, 1989, p. 192). Roediger and Thorpe (1978) have claimed that hypermnesia occurs because the act of retrieving information makes it more accessible in the future. They base their account on stimulus sampling theory (Estes, 1955), and posit that the gains associated with hypermnesia may be due to repeated sampling of memory items, with the items sampled changing over time as a result of 'inherent variability' in the population of items in the search set. (Incidentally, a possible theoretical rationale for this variability was suggested in the previous section).

Roediger and Thorpe (1978) have elaborated on this proposal, and argue that improvements in recall over time stems from changes in the internal cues subjects use during recall. The latter possibility seems particularly relevant as an explanation of hypermnesia with categorised lists. For instance, a study by Payne (1986) has shown that increases in recall on such lists derive from the addition of novel categories, rather than more items from categories already recalled on a previous trial. The suggestion here is that the subjects may be cuing themselves by thinking of category names on subsequent trials. The present study provides further support for this position. The analysis conducted in the previous chapter showed that the majority of the items gained over trials were items from novel categories. Furthermore, most of the items gained from categories recalled on previous trials belonged to the two categories defined as salient, whereas most of the items gained from novel categories belonged to the non-salient categories. These results suggest that the subjects found the salient categories easy to access, in that they were quickly activated and only incrementally enlarged over successive trials. On the other hand, the non-salient categories were activated more slowly and were more likely to become available on later trials.

Given these data, the hypermnesic effect seems compatible with the theoretical framework underlying this study. If we assume that categories are not equally salient, then we can also predict that they will be differentially activated during cognitive tasks. Salient categories will be easier to access than non-salient categories (because the exemplars of the former are more strongly interconnected than those from the latter). The implication here is that salient categories are easier to access and hence will be activated more quickly during memory processes than non-salient categories. Hypermnesia may be a logical consequence of such differential rates of access associated with cognitive categories.

5.5 How organisation facilitates recall

It is often assumed in the literature that there is an interdependence between levels of clustering and recall. Thus many researchers claim that clustering underlies an organisational strategy intended to maximise recall by exploiting categorial relations between the items to be remembered, so that high clusterers will necessarily also achieve high levels of recall (see e.g. Cooke, Schvaneveldt & Durso, 1986; Ornstein &

Corsale, 1979). However, in this study the adults obtained significantly higher levels of recall than the children on both lists, but the levels of clustering as measured by the ratio of repetition observed in the L1 protocols of the 6-year-old children and adults were largely similar. Given the typical correlation between amount of clustering and recall, the adults and the 6-year-old children should have attained roughly equivalent levels of recall, because they exhibited similar levels of clustering.

Further, in terms of the theoretical framework set out in Section 2.3, the clustering or organisation in recall output would seem to be a kind of epihenomenon, a by-product associated with the processing of organisational structures in the knowledge base. Thus we can postulate that strong relational links augment the accessibility, and hence recall, of items in the knowledge base (because activation spreads quickly down strongly weighted links), and that such items will be clustered in recall. The finding that differences in the recall of the TBR items occurred despite equivalent levels of clustering is evidently problematic for our position.

The first point to bear in mind is that the proximity analysis of the children's protocols yielded different levels of hierarchical grouping for the different categories. In other words, the ratio of repetition produced an index of clustering, and the cluster analysis of the proximity data showed which categories were in fact the most clustered. This means that even though the 6-year-olds and the adults received similar cluster ratings in terms of the ratio of repetition index, their clustering did not range over all categories to the same extent. In fact, the adults' clustering was fairly uniformly distributed over all the categories, whereas the children's clustering appeared to be more biased to a subset of the salient categories. One reason for the latter phenomenon was given in Section 5.3, where we argued that differential patterns of activation might have contributed to the failure to observe significant increases in clustering (and recall) over trials in the children's protocols.

Such differences in activation may also underlie the different degrees of accessibility, and hence different levels of clustering, associated with the salient categories in the children's protocols. Why should differences in the allocation of clustering efforts have an effect on recall? Possibly because the children's clustering is still largely non-strategic (i.e. mediated by adaptive mechanisms in the knowledge base), and hence not necessarily optimal for actual recall of the particular stimulus set.

There is probably a trade-off between the use of 'ready-made' clusters (e.g. frequently encountered conceptual taxonomies) encoded in the knowledge base, and the construction of clusters at least partially 'on the fly'. In some cases the latter option might lead to more efficient memory performance. Known clusters might prove unwieldy under certain circumstances, so that even if children have acquired fairly elaborate knowledge structures associated with categories, they might still experience difficulty in adapting these structures to the recall of the specific items in a stimulus set. This could easily happen where the set consists of items from a number of different categories, presented (as in the present study) in an unfamiliar sequence. Consider now the following aspects:

Firstly, the adults have more elaborate knowledge bases than the children. This much seems uncontentious. Adults know more about most things than young children, they have more item-specific information in their knowledge, their conceptual structures are richer and more hierarchically encoded than those of young children. Furthermore, adults are also more strategic in their recall than young children. For instance, in this study the adults showed evidence of an organisational strategy in their recall of L1 and L2, whereas the children only exhibited significant levels of clustering in their recall of L1.

We can now reason as follows. In all likelihood, the levels of clustering observed in the children's recall were still largely mediated by automatic factors in their knowledge bases, and are only indicative of an emerging strategic functioning. In contrast, the adults have more elaborate knowledge bases, and are therefore more flexible in their use of associative and organisational strategies than children. Because the adults are more flexible (they have more groupings to chose from) in their use of organisational strategies they are more likely than children to adapt such strategies to the target material.

Indeed, it is quite possible that the children clustered the TBR items either unconsciously or on the basis of an intuitive appreciation of similarity, but without a clear retrieval plan in mind. The morale of all of this is that the adults' clustering may be more goal-directed than that of the children, so that the organisation observed in the former's protocols would be more likely to enhance recall than in the case of the latter.

5.6 Some remaining issues

The most important result emerging from the study is that the manipulation of category type has an effect on the children's memory performance. Indeed, it appears that differences in the degree of saliency that children attach to categories can induce performance differences in both level of recall and clustering. Salient categories tend to exhibit a more hierarchical ordering than non-salient categories, which suggests that an emergent organisational strategy mediates the processing of members of salient categories during memory tasks. In addition the hypermnesic experiment indicates that salient categories are easily activated, and hence accessed, in the course of memory search and retrieval processes. Together these findings attest to the role of the knowledge base, both in recall and in the acquisition of memory strategies. In as much as the study has uncovered some of the factors underlying early memory development, it makes a contribution to cognitive-developmental theory. Yet, many questions remain unanswered, and some important issues deserve closer scrutiny. Some of these are set out below.

In the study it is postulated that there is a gradual transition from automatic to controlled processing during the course of memory development. This sequence seems counterintuitive if viewed in the light of current work on cognitive learning, where it is often assumed that performance on novel tasks initially relies on controlled processing, and becomes automatic following protracted periods of practice (e.g., Cohen, McClelland & Dunbar, 1990; Logan, 1988). In other words, the general assumption is that the transition in cognitive learning is from controlled to automatic processes rather than from automatic to controlled performance as posited here. However, there is now also a substantial body of research in psychology attesting to the fact that learning frequently occurs in an incidental and unconscious manner (Reber, 1989). These studies show that learning can take place without the learner having any explicit awareness either of the learning experience as such, or even of the resultant knowledge (Cleeremans & McClelland, 1991). Such learning behaviour seems to apply to the early development of memory, in that metamemorial ability (i.e. control over the functioning of the memory system) gradually emerges from what we took to be a more primitive, highly automatised processing system.

It makes sense to posit that strategic processes emerge gradually from an automatic component if we assume that strategies are effortful and that there is a limited amount of cognitive resources available to the learner. In such a framework increased automatisation of the cognitive system gradually frees cognitive resources which can then be allocated to the development of memory strategies. Nevertheless, the automatic, unconscious and indeed 'implicit' nature of early memory processing needs further exploration, particularly in the light of the now burgeoning literature on implicit memory (see e.g. Schachter, 1987 for a review).

Also, we have relied on a conception of the knowledge base in terms of which relational structures, and hence conceptual taxonomies, are fairly static entities. As indicated in Section 5.5, such a view may be too restrictive, and a model allowing for dynamic aspects of memory processing is probably called for. A clue as to how the present framework can be extended to incorporate dynamic memory processes can be gleaned from Newell (1990). Newell (see also Newell & Rosenbloom, 1981) uses the term *chunking* (borrowed from Miller, 1956) to denote clustering, and relates the phenomenon of chunking to the power law of practice. This law attempts to account for the speedup factor (i.e. increases in response time) generally observed on learning tasks, and states that if the logarithm of the reaction time on a cognitive task is plotted against the logarithm of the number of practice trials, the result is a downward-sloping straight line (Newell, 1990, p. 6).

Newell claims that the notion of chunking provides a theoretical explanation for the power law of practice. His proposal is based on the propositions that chunking is a ubiquitous feature of cognition, that it enhances cognitive performance because once a chunk has been formed it can be evoked as a kind of 'subroutine' in other cognitive tasks, and that the higher a chunk is in the conceptual hierarchy, the less useful it becomes, because the situations in which it is used decrease. Assuming therefore a constant rate of chunking, the speedup resulting from the chunking yields exponential learning, but as higher level chunks are formed their usefulness begins to decline so that the rate of learning slows down, and changes from an exponential to a power function (see Newell, 1990, p. 8). Newell's exposition highlights the adaptive nature of chunking (i.e. clustering), and shows how the mechanism of chunking might contribute to the optimisation of cognitive functions (a point also touched upon in Section 5.5.). Yet, his treatment of these issues is rather speculative, and clarity is needed about questions such as: At what stage exactly do clusters become maladaptive? By what processes are they formed? Are frequently occurring clusters encoded as fixed structures in the knowledge base or are they created during the course of processing the relevant information? The nature of these adaptive aspects underlying human categorisation clearly merit further exploration (see Anderson, 1991 in this respect).

Finally, although the study has explored some aspects associated with the acquisition and refinement of categorial structures by young children, it has only started to delve into the cognitive processes implicated in the development of this knowledge. The level of theorising in this study remains rather broad and general, and lacks the specificity and quantitative precision that are needed to gain deeper insight into the nature of underlying cognitive mechanisms. Part of the problem is that standard empirical procedures used in developmental psychology do not really lend themselves to the investigation of the complex, often highly interactive and dynamic processes associated with higher cognitive functions such as memory and language. Indeed, there are increasingly indications that it might be necessary to combine such empirical procedures with fairly sophisticated modelling techniques (see e.g., Brainerd, 1987; Estes, 1991).

Lately, connectionist models have become popular in psychology, and this computer modelling approach to the testing of cognitive theories may well turn out be the preferred avenue in future for exploring developmental processes in a more rigorous manner (e.g. Rabinowitz, Lesgold & Berardi, 1988; Rabinowitz & McAuley, 1990; Smolensky, 1989). This does not mean that the research conducted in this study is without merit. At the very least it paves the way for more refined and detailed exploration by describing a theoretical framework in terms of which subsequent research can be pursued. Further, although only part of a much larger theoretical problem has been explored, this is all pretty much unchartered country and every step counts.

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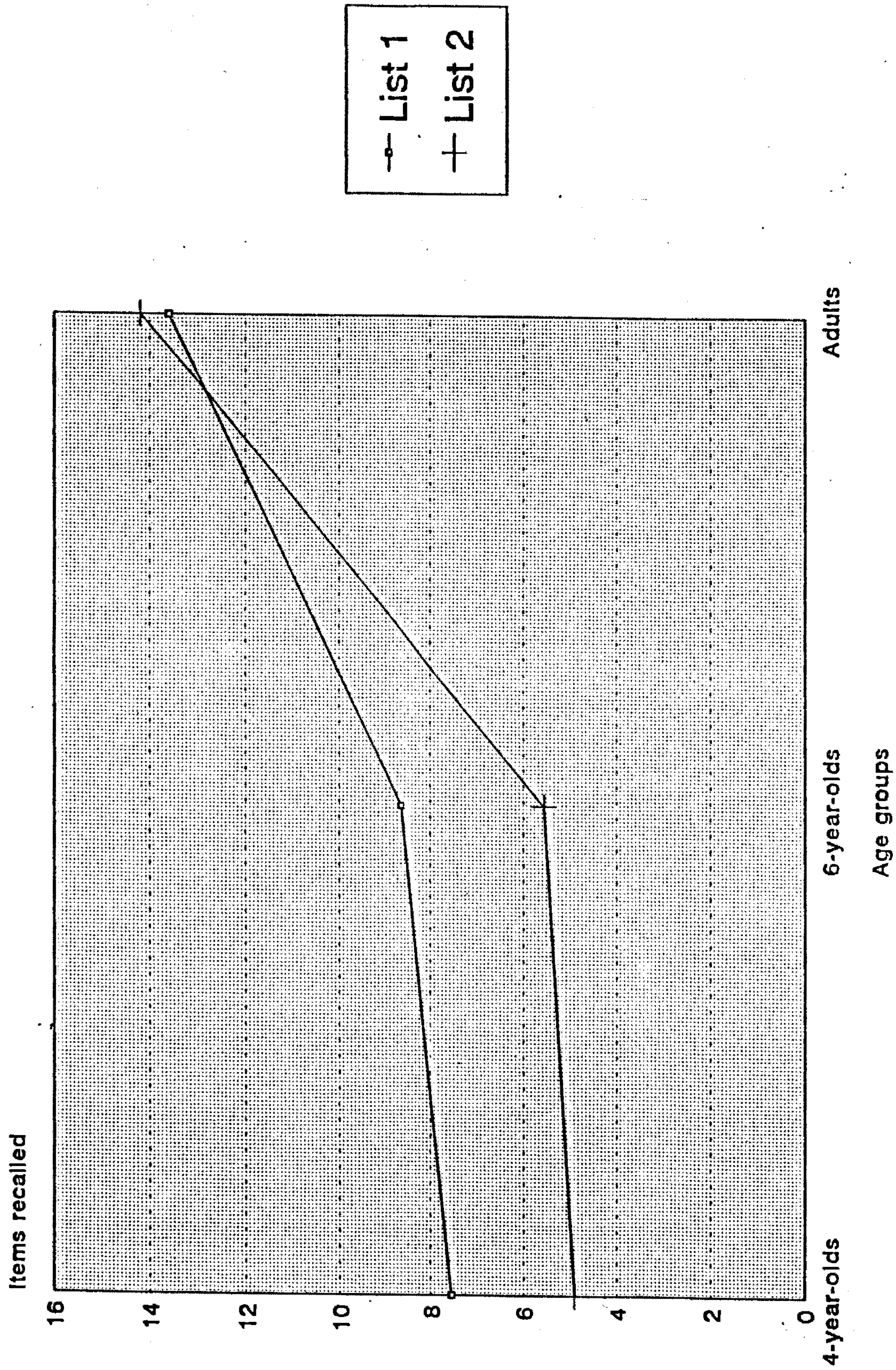
Appendix A

Figures 1-13

Figure 1. Mean levels of recall as a function of age and list, for trials 1-3 combined.



Note: Figures 1-10: Experiment 1
Figures 11-13: Experiment 2

Figure 2. Mean levels of recall for L1 as a function iof age and trials.

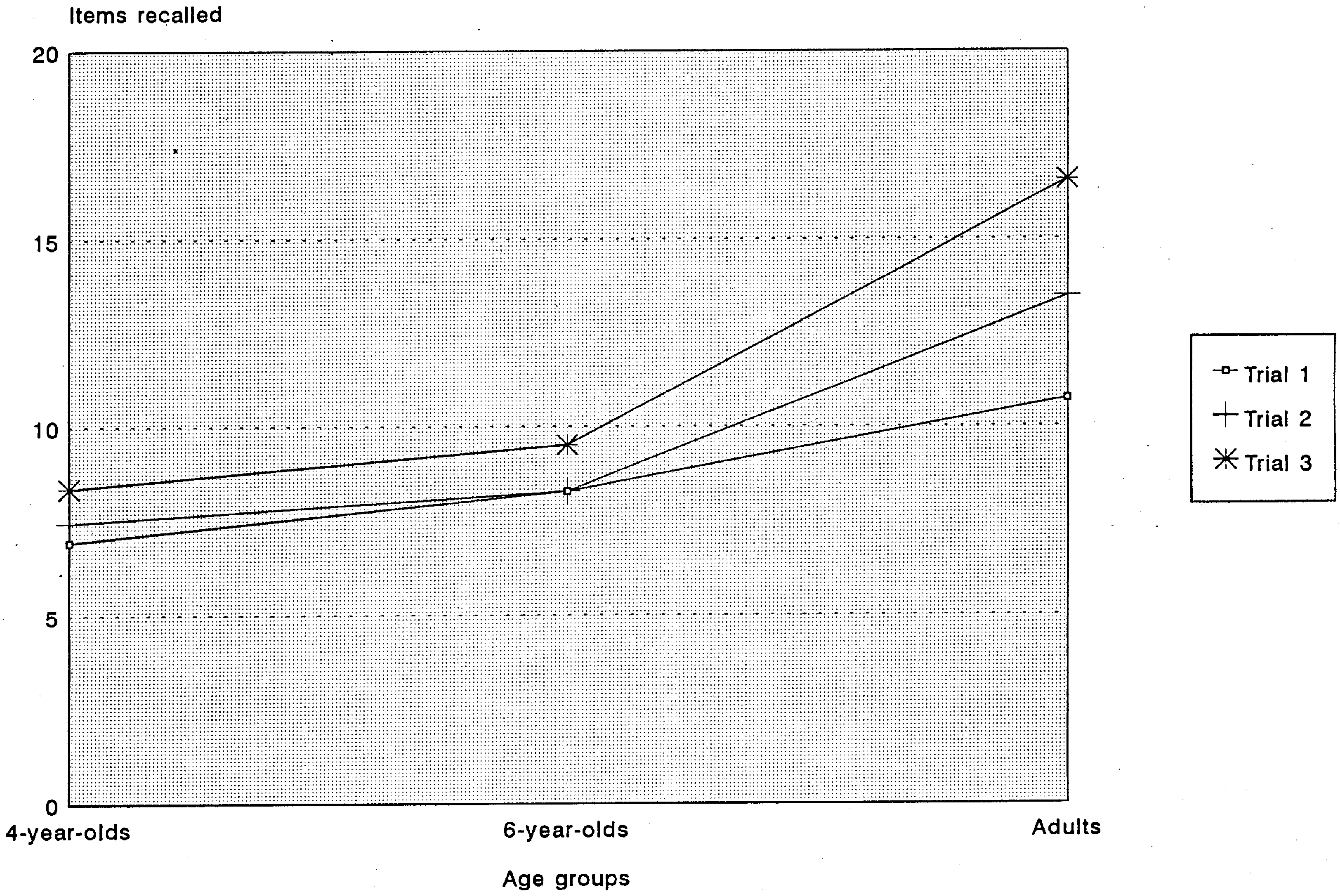


Figure 3. Mean levels of recall for L2 as a function of age and trials.

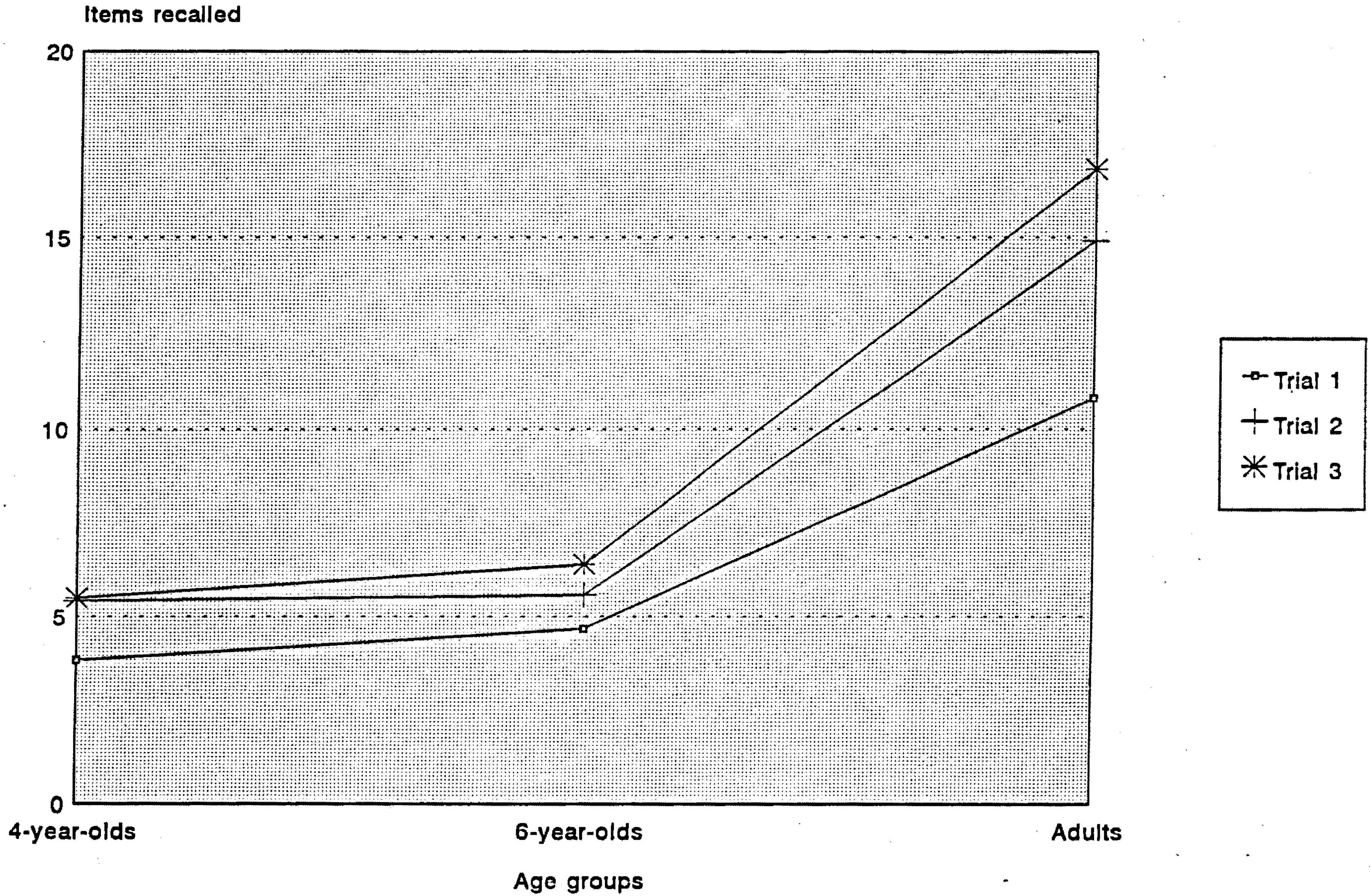


Figure 4. Mean levels of clustering as measured by the ratio of repetition.

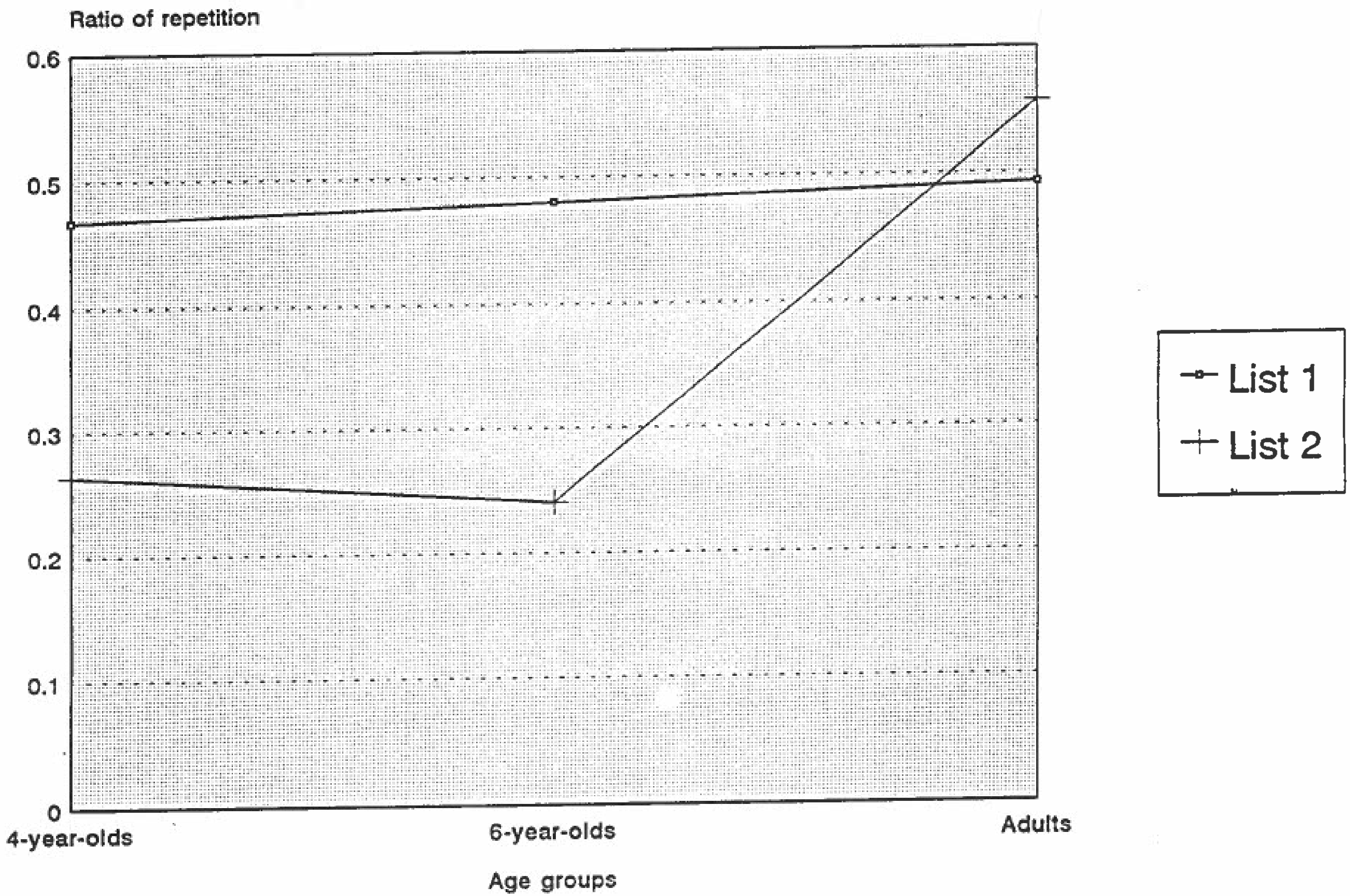
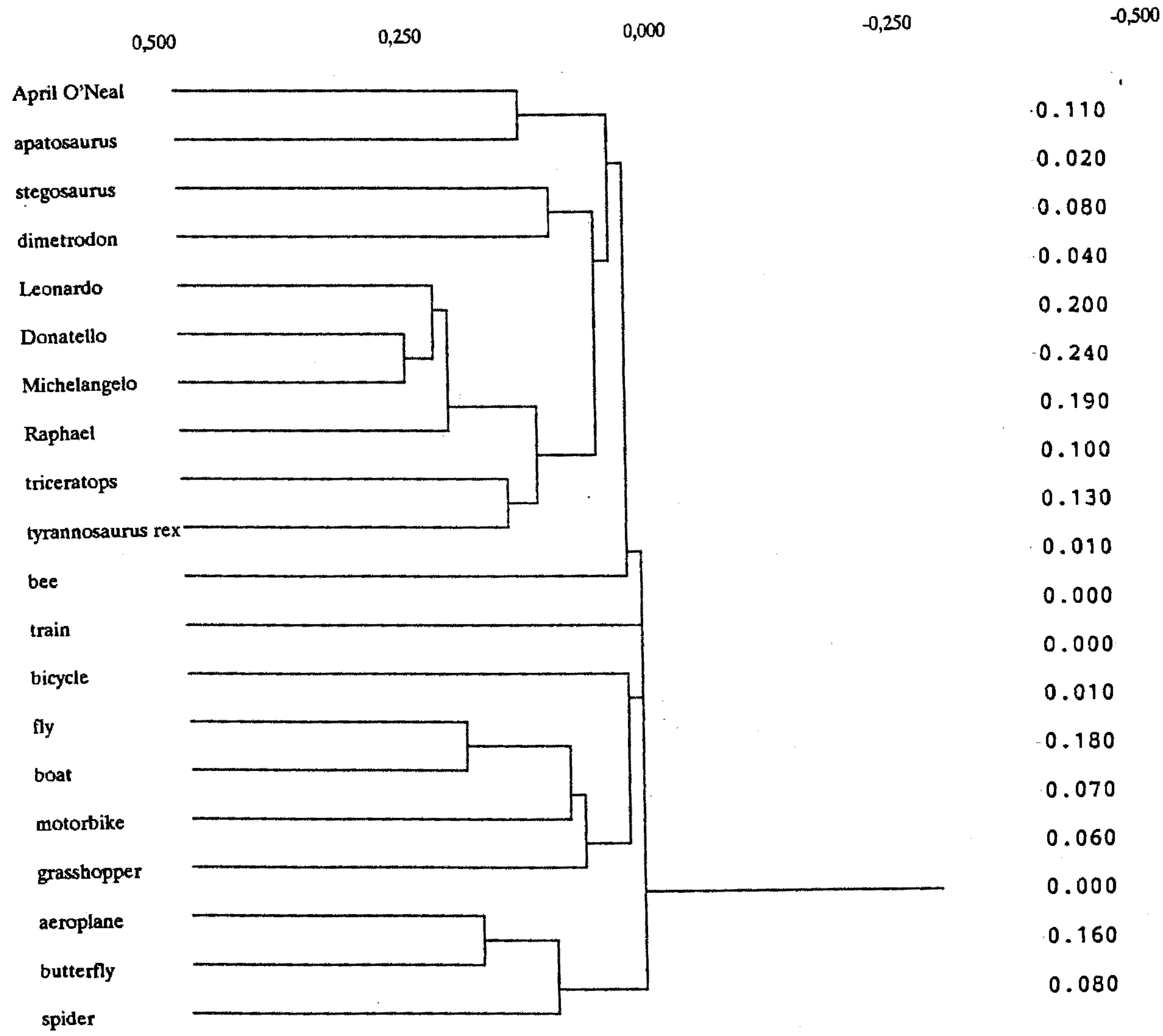


Figure 5. **Hierarchical cluster solution yielded by the proximity data obtained from the L1 recall protocols produced by the 4-year-olds.**

COMPLETE LINKAGE METHOD (FARTHEST NEIGHBOUR)

TREE DIAGRAM SIMILARITIES



Note: To facilitate the interpretation of the cluster solutions, the exact points at which the relevant clusters merge are indicated in the vertical column provided next to each tree diagram. These points have been calculated by computer, but can be verified by reading off the relevant values from the horizontal scale provided on the top of the tree diagrams.

Figure 6. **Hierarchical cluster solution yielded by the proximity data obtained from the L2 recall protocols produced by the 4-year-olds.**

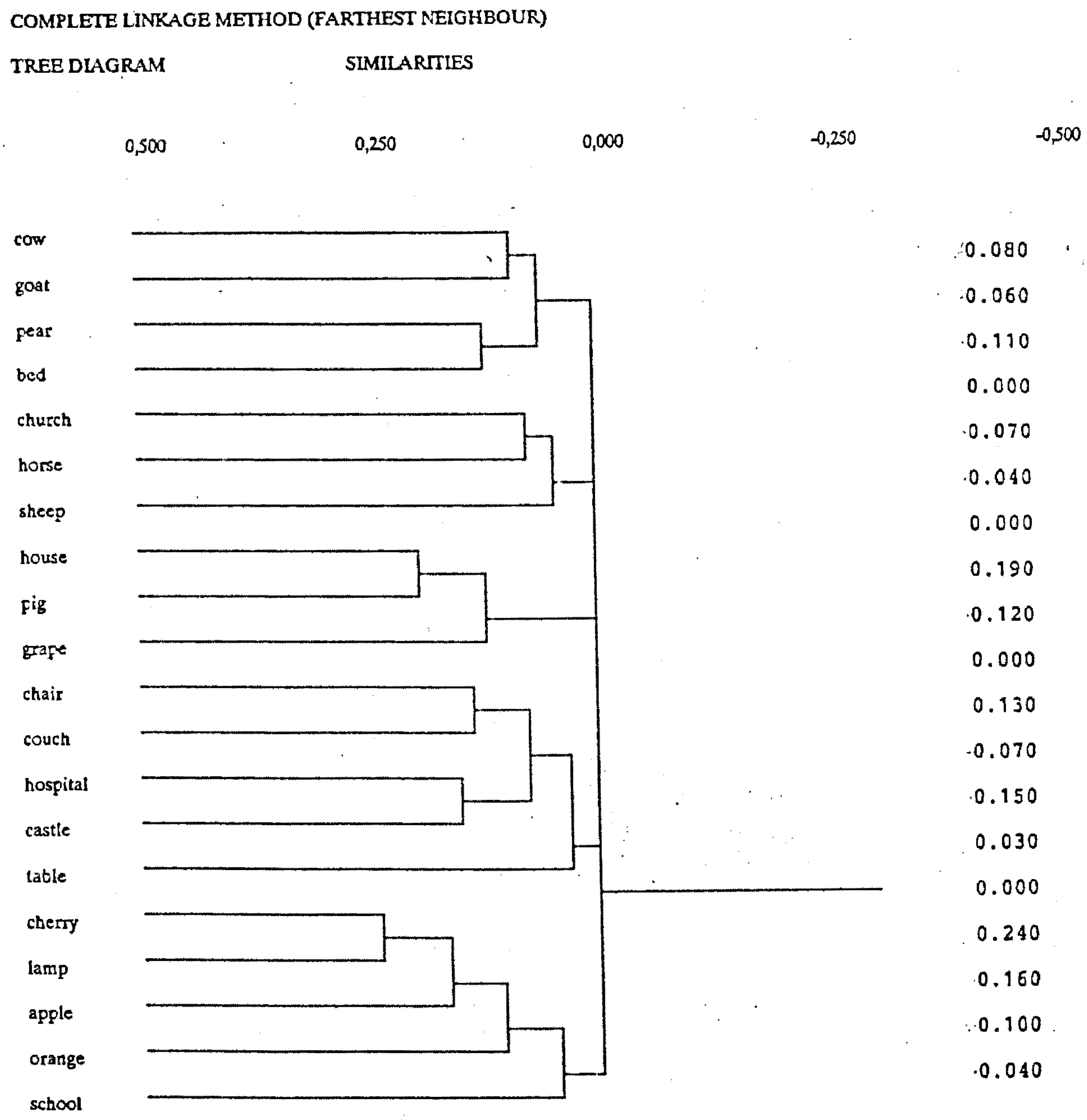


Figure 7. **Hierarchical cluster solution yielded by the proximity data obtained from the L1 recall protocols produced by the 6-year-olds**

COMPLETE LINKAGE METHOD (FARTHEST NEIGHBOUR)

TREE DIAGRAM SIMILARITIES

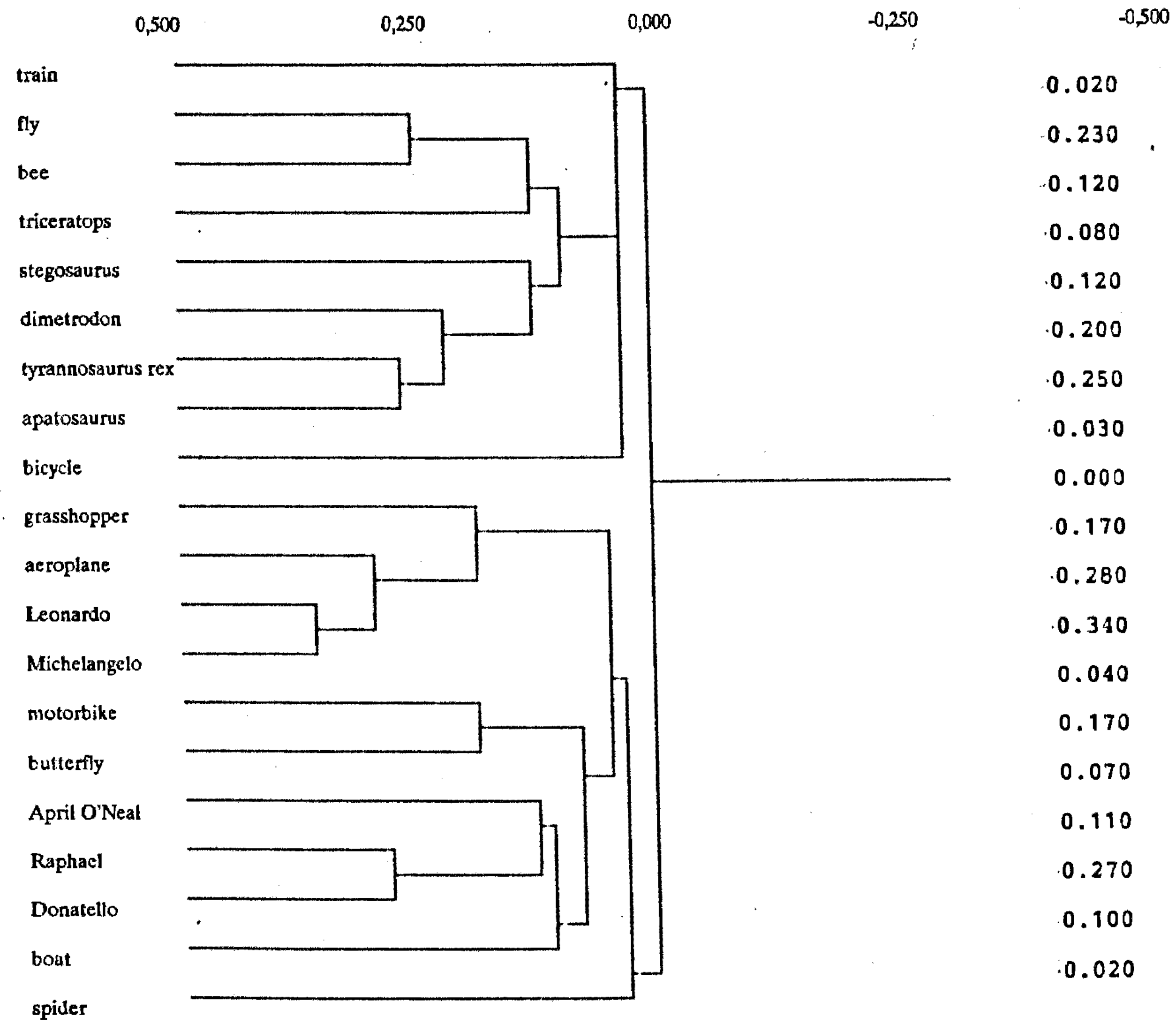


Figure 8. **Hierarchical cluster solution yielded by the proximity data obtained from the L2 protocols produced by the 6-year-olds.**

COMPLETE LINKAGE METHOD (FARTHEST NEIGHBOUR)

TREE DIAGRAM SIMILARITIES

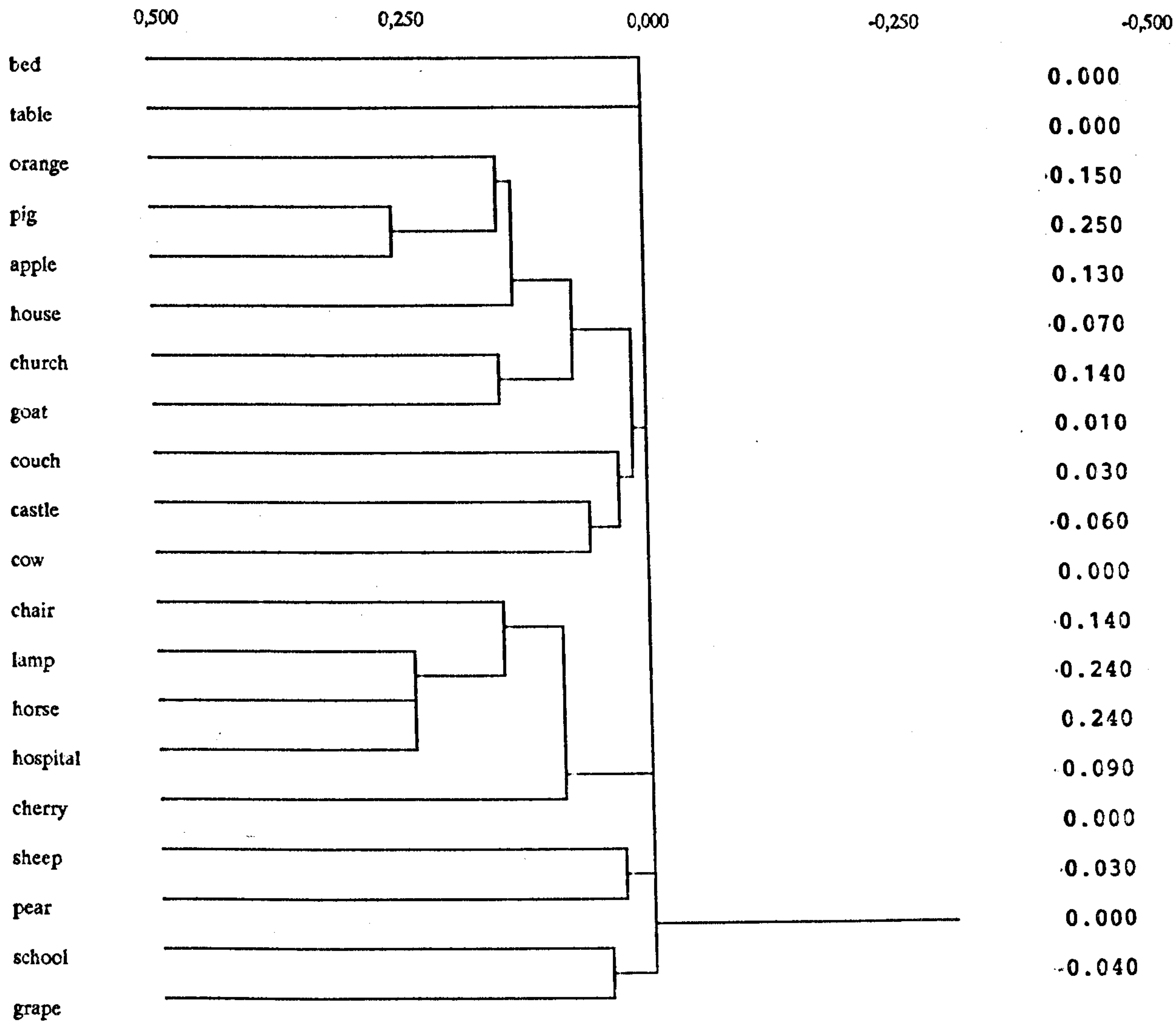


Figure 9. **Hierarchical cluster solution yielded by the proximity data obtained from the L1 recall protocols produced by the adults.**

COMPLETE LINKAGE METHOD (FARTHEST NEIGHBOUR)

TREE DIAGRAM SIMILARITIES

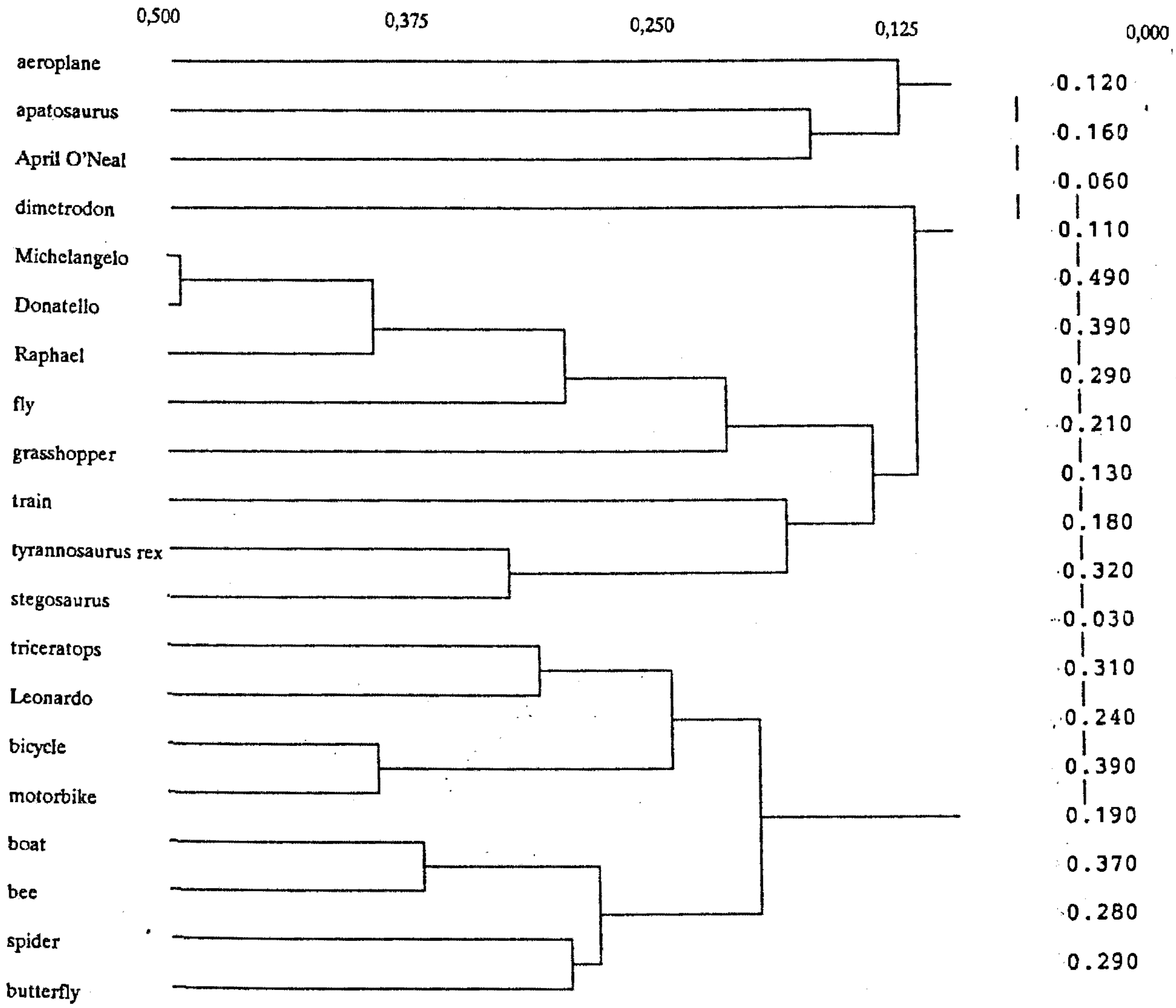
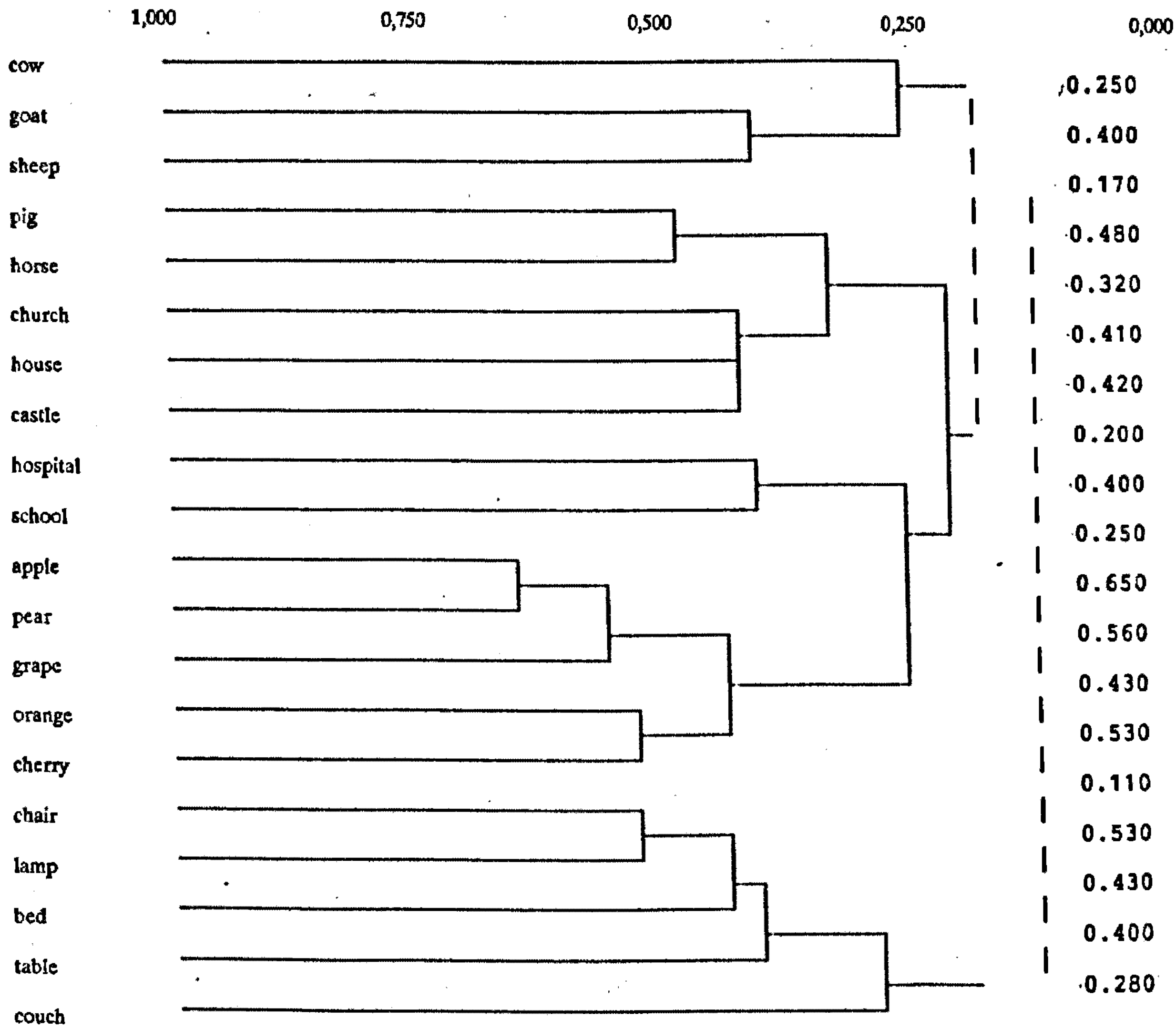


Figure 10. Hierarchical cluster solution yielded by the proximity data obtained from the L2 recall protocols produced by the adults.

COMPLETE LINKAGE METHOD (FARTHEST NEIGHBOUR)

TREE DIAGRAM SIMILARITIES



Note: The range is set between 1,000 and 0,000 in this cluster solution to allow for the higher proximity values yielded by the adults' recall with this list.

Figure 11. Mean level of recall as a function of category type and trial in Experiment 2.

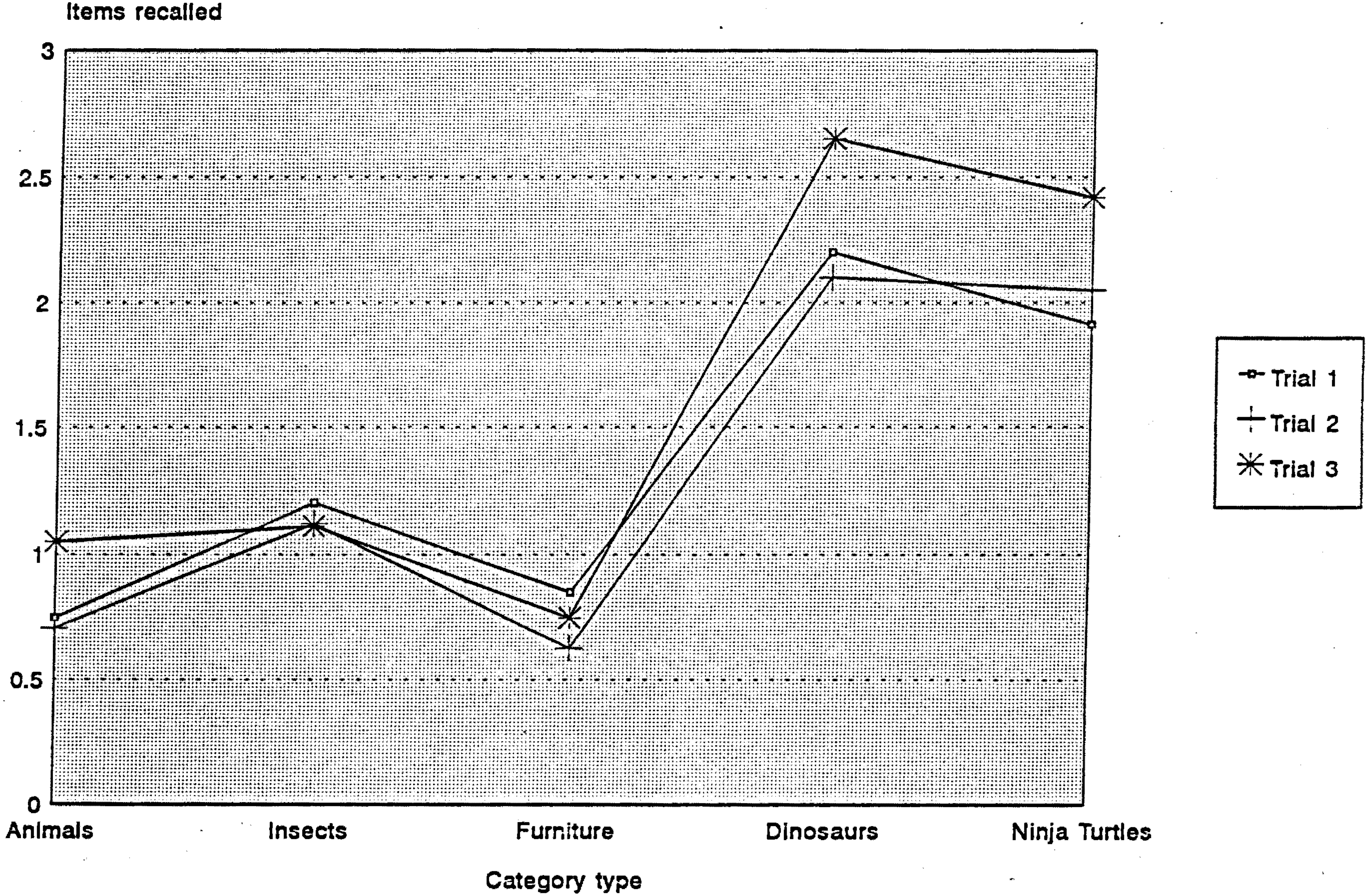


Figure 12. Mean levels of clustering, as measured by the ratio of repetition, expressed as a function of trials.

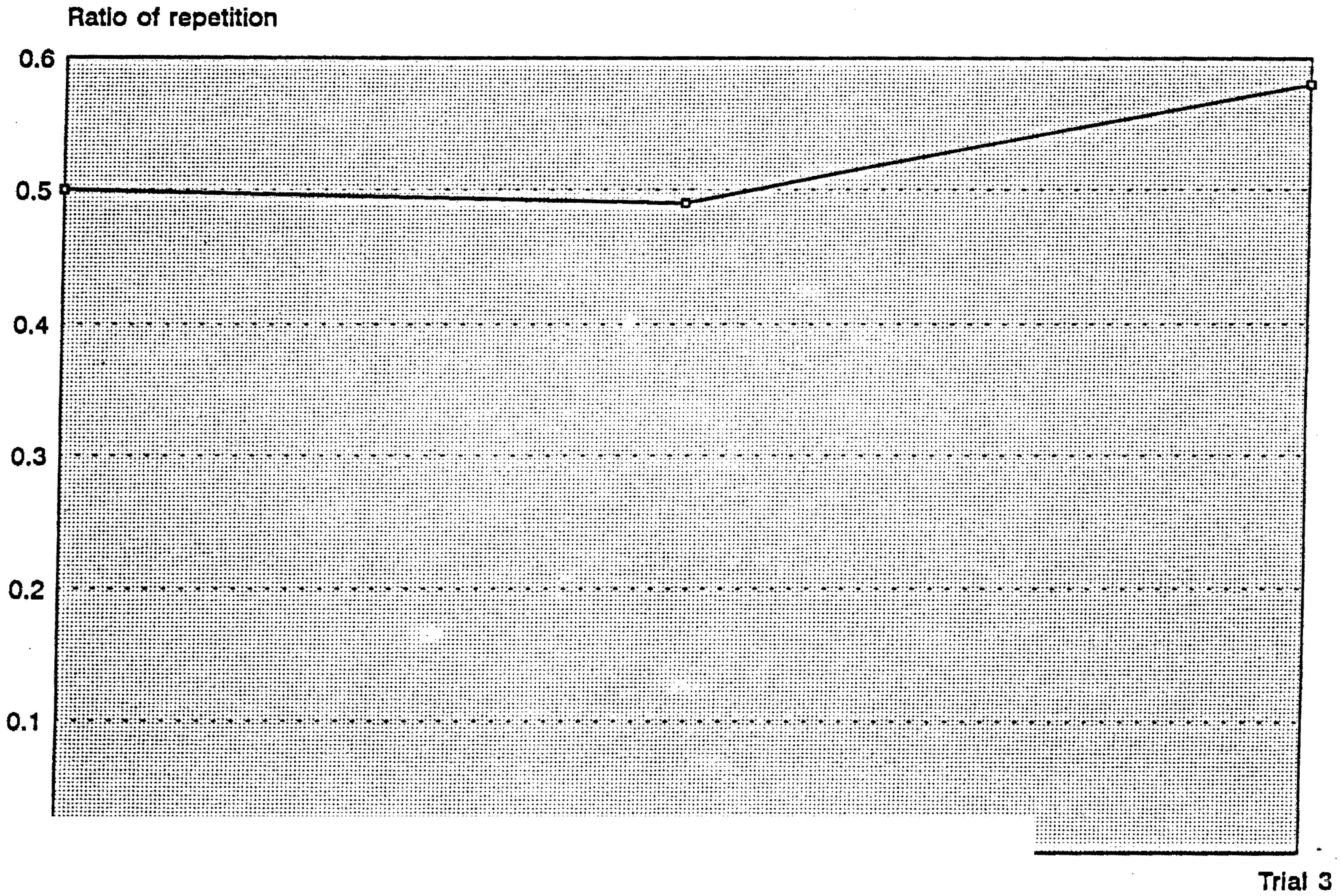
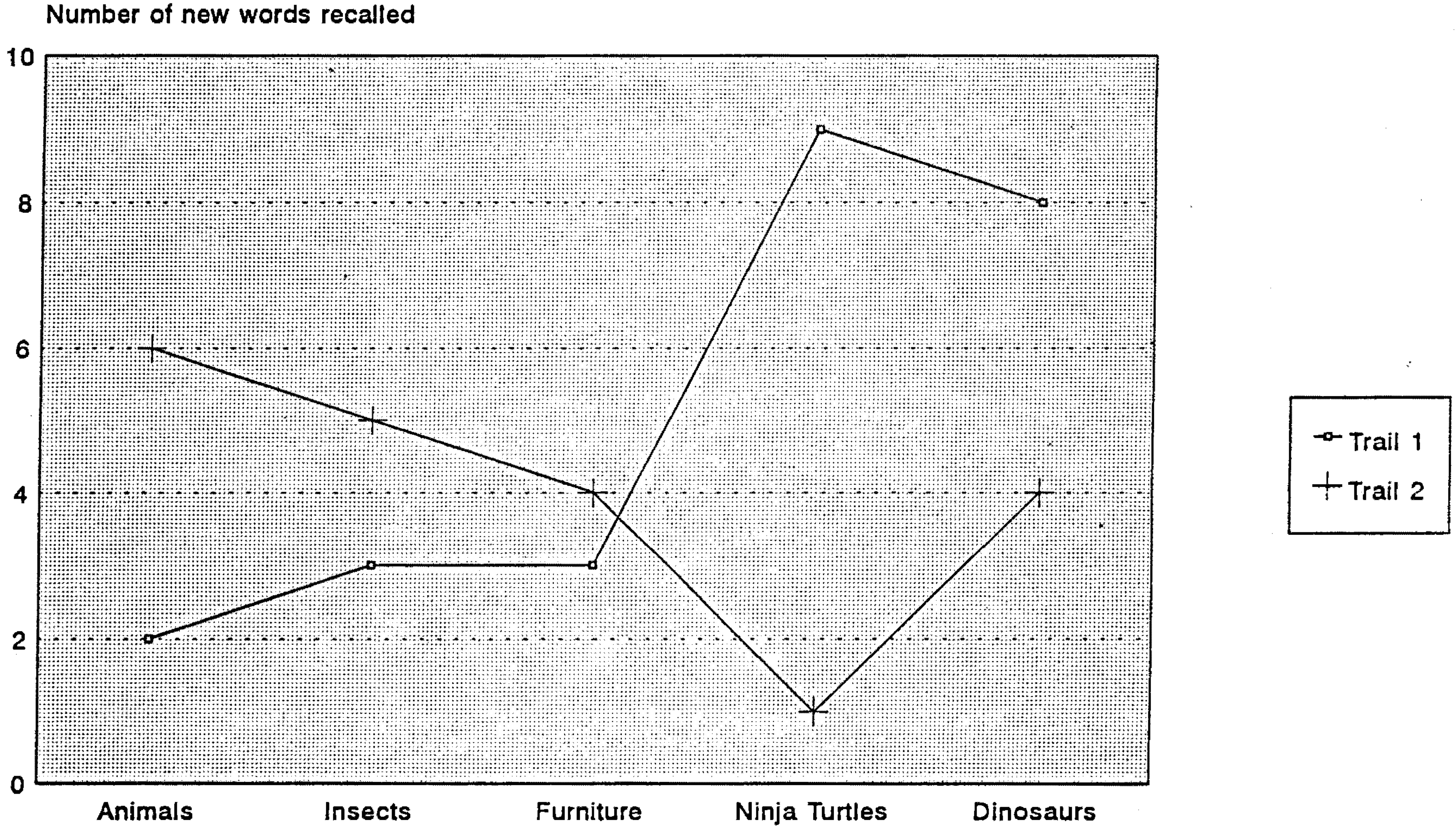


Figure 13. Number of new words recalled as a function of category type and trial.



	Animals	Insects	Furniture	Ninja Turtles	Dinosaurs
Trail 1	2	3	3	9	8
Trail 2	6	5	4	1	4

Category type

TABLE 5

Proximity matrix yielded by analysis of the recall protocols produced by the 4-year-olds on L1

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
a	X																			
b	0.13	X																		
c	0.10	0.06	X																	
d	0.08	0.08	0.08	X																
e	0.10	0.02	0.06	0.09	X															
f	0.14	0.10	0.10	0.07	0.05	X														
g	0.14	0.11	0.10	0.08	0.06	0.20	X													
h	0.13	0.12	0.08	0.08	0.06	0.20	0.19	X												
i	0.13	0.14	0.06	0.04	0.07	0.24	0.23	0.24	X											
j	0.11	0.07	0.04	0.05	0.11	0.06	0.09	0.09	0.13	X										
k	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.01	X									
l	0.02	0.04	0.00	0.03	0.00	0.01	0.00	0.02	0.01	0.01	0.00	X								
m	0.03	0.04	0.00	0.01	0.00	0.03	0.01	0.00	0.06	0.00	0.00	0.05	X							
n	0.13	0.11	0.06	0.05	0.00	0.11	0.08	0.11	0.18	0.04	0.05	0.04	0.05	X						
o	0.10	0.16	0.02	0.07	0.05	0.12	0.08	0.08	0.12	0.09	0.00	0.06	0.07	0.13	X					
p	0.02	0.09	0.04	0.02	0.02	0.11	0.04	0.07	0.18	0.06	0.01	0.01	0.08	0.11	0.18	X				
q	0.03	0.02	0.01	0.02	0.02	0.06	0.07	0.07	0.14	0.05	0.04	0.00	0.02	0.09	0.04	0.11	X			
r	0.02	0.03	0.02	0.01	0.01	0.05	0.04	0.04	0.03	0.01	0.00	0.00	0.00	0.04	0.08	0.07	0.00	X		
s	0.00	0.02	0.00	0.01	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.07	0.01	0.06	0.10	0.00	0.00	X	
t	0.04	0.07	0.03	0.00	0.00	0.06	0.04	0.09	0.13	0.01	0.01	0.00	0.12	0.16	0.07	0.15	0.08	0.04	0.07	X

Key: a=tyrannosaurus rex, b=triceratops, c=stegosaurus, d=dimetrodon, e=apatosaurus, f=Michelangelo, g=Leonardo, h=Raphael, i=Donatello, j=April O'Neal, k=train, l=bicycle, m=motorbike, n=aeroplane, o=boat, p=fly, q=spider, r=bee, s=grasshopper, t=butterfly.

TABLE 6
Proximity matrix yielded by analysis of the recall protocols produced by the 4-year-olds on L2

		b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
		X																		
		0.08	X																	
		0.03	0.04	X																
		0.15	0.00	0.04	X															
		0.08	0.05	0.06	0.09	X														
		0.01	0.01	0.05	0.00	0.00	X													
		0.03	0.00	0.00	0.00	0.05	0.00	X												
		0.02	0.00	0.07	0.00	0.03	0.04	0.00	X											
		0.00	0.03	0.01	0.00	0.00	0.00	0.08	0.00	X										
		0.10	0.01	0.06	0.14	0.05	0.02	0.00	0.02	0.00	X									
		0.11	0.02	0.00	0.03	0.06	0.00	0.02	0.00	0.00	0.05	X								
		0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.06	0.00	0.00	X							
		0.07	0.01	0.03	0.09	0.03	0.00	0.00	0.00	0.00	0.13	0.03	0.00	X						
		0.11	0.04	0.08	0.09	0.06	0.05	0.00	0.05	0.02	0.09	0.05	0.00	0.06	X					
p	0.17	0.09	0.08	0.02	0.07	0.05	0.04	0.08	0.02	0.09	0.11	0.05	0.05	0.06	0.16	X				
q	0.11	0.12	0.04	0.05	0.05	0.02	0.07	0.00	0.05	0.00	0.08	0.08	0.00	0.04	0.10	0.14	X			
r	0.07	0.00	0.03	0.00	0.04	0.05	0.00	0.09	0.00	0.09	0.00	0.00	0.11	0.00	0.00	0.12	0.00	X		
s	0.12	0.03	0.03	0.07	0.06	0.13	0.00	0.00	0.02	0.00	0.04	0.00	0.00	0.02	0.06	0.00	0.07	0.04	X	
t	0.09	0.06	0.06	0.03	0.06	0.01	0.04	0.05	0.01	0.10	0.10	0.02	0.03	0.07	0.24	0.21	0.10	0.06	0.05	X

Key: a h=cow, i=horse, j=goat,
k=ch s=grape, t=cherry.

TABLE 7

Proximity matrix yielded by analysis of the recall protocols produced by the 6-year-olds on L1

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
a	X																			
b	0.12	X																		
c	0.15	0.11	X																	
d	0.24	0.08	0.13	X																
e	0.25	0.09	0.12	0.20	X															
f	0.19	0.15	0.11	0.18	0.16	X														
g	0.20	0.16	0.09	0.17	0.11	0.34	X													
h	0.18	0.12	0.14	0.18	0.11	0.24	0.18	X												
i	0.16	0.10	0.08	0.17	0.15	0.29	0.26	0.27	X											
j	0.13	0.03	0.05	0.14	0.11	0.12	0.13	0.11	0.13	X										
k	0.08	0.02	0.02	0.06	0.03	0.03	0.05	0.05	0.03	0.04	X									
l	0.05	0.03	0.03	0.07	0.06	0.03	0.02	0.03	0.03	0.00	0.02	X								
m	0.10	0.04	0.06	0.10	0.08	0.08	0.05	0.07	0.07	0.08	0.04	0.08	X							
n	0.17	0.11	0.05	0.11	0.14	0.29	0.28	0.13	0.23	0.09	0.13	0.00	0.11	X						
o	0.15	0.03	0.04	0.09	0.11	0.19	0.07	0.13	0.11	0.10	0.03	0.03	0.07	0.11	X					
p	0.11	0.12	0.09	0.09	0.10	0.15	0.10	0.17	0.13	0.21	0.05	0.04	0.15	0.07	0.15	X				
q	0.05	0.02	0.01	0.01	0.03	0.02	0.03	0.06	0.07	0.02	0.01	0.00	0.02	0.06	0.02	0.08	X			
r	0.17	0.12	0.08	0.13	0.17	0.17	0.14	0.14	0.11	0.10	0.04	0.06	0.09	0.10	0.11	0.23	0.03	X		
s	0.14	0.05	0.03	0.04	0.13	0.17	0.20	0.07	0.12	0.06	0.00	0.05	0.04	0.17	0.09	0.10	0.04	0.14	X	
t	0.11	0.02	0.04	0.07	0.06	0.09	0.04	0.13	0.13	0.16	0.04	0.02	0.17	0.15	0.09	0.20	0.06	0.15	0.09	X

Key: a=tyrannosaurus rex, b=triceratops, c=stegosaurus, d=dimetrodon, e=apatosaurus, f=Michelangelo, g=Leonardo, h=Raphael, i=Donatello, j= April O'Neal, k=train, l=bicycle, m=motorbike, n=aeroplane, o=boat, p=fly, q=spider, r=bee, s=grasshopper, t=butterfly

TABLE 8

Proximity matrix yielded by analysis of the recall protocols produced by the 6-year-olds on L2

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
a	X																			
b	0.11	X																		
c	0.08	0.05	X																	
d	0.12	0.18	0.02	X																
e	0.06	0.08	0.00	0.01	X															
f	0.13	0.08	0.04	0.09	0.03	X														
g	0.02	0.05	0.00	0.04	0.02	0.04	X													
h	0.04	0.05	0.00	0.02	0.06	0.04	0.06	X												
i	0.14	0.24	0.02	0.15	0.10	0.15	0.10	0.09	X											
j	0.11	0.09	0.02	0.14	0.02	0.10	0.02	0.01	0.05	X										
k	0.06	0.16	0.01	0.07	0.07	0.13	0.04	0.05	0.05	0.00	X									
l	0.01	0.02	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.02	X								
m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	X							
n	0.02	0.05	0.02	0.02	0.03	0.02	0.00	0.04	0.04	0.02	0.10	0.03	0.00	X						
o	0.10	0.24	0.05	0.12	0.10	0.12	0.05	0.08	0.24	0.12	0.17	0.00	0.01	0.05	X					
p	0.17	0.15	0.04	0.11	0.04	0.25	0.04	0.02	0.11	0.10	0.22	0.02	0.00	0.04	0.19	X				
q	0.14	0.11	0.06	0.09	0.02	0.15	0.05	0.02	0.15	0.07	0.09	0.02	0.01	0.02	0.18	0.23	X			
r	0.04	0.02	0.03	0.00	0.00	0.04	0.03	0.02	0.02	0.03	0.00	0.00	0.00	0.00	0.03	0.07	0.08	X		
s	0.01	0.11	0.00	0.07	0.04	0.01	0.03	0.05	0.06	0.04	0.09	0.00	0.02	0.00	0.09	0.02	0.05	0.00	X	
t	0.09	0.11	0.04	0.06	0.02	0.06	0.02	0.00	0.11	0.04	0.09	0.02	0.00	0.02	0.21	0.18	0.07	0.04	0.00	X

church, e=castle, f=pig, g=sheep, h=cow, i=horse, j=goat,
ımp, p=apple, q=orange, r=pear, s=grape, t=cherry.

TABLE 9

Proximity matrix yielded by analysis of the recall protocols produced by the adults on L1

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
a	X																			
b	0.30	X																		
c	0.32	0.31	X																	
d	0.15	0.14	0.21	X																
e	0.17	0.18	0.22	0.10	X															
f	0.29	0.27	0.23	0.16	0.10	X														
g	0.18	0.31	0.19	0.13	0.13	0.37	X													
h	0.28	0.30	0.22	0.11	0.15	0.43	0.37	X												
i	0.25	0.26	0.21	0.12	0.13	0.49	0.31	0.39	X											
j	0.17	0.18	0.18	0.15	0.16	0.23	0.19	0.22	0.25	X										
k	0.18	0.15	0.19	0.12	0.13	0.27	0.10	0.13	0.25	0.10	X									
l	0.26	0.24	0.19	0.15	0.11	0.34	0.26	0.26	0.22	0.14	0.17	X								
m	0.25	0.32	0.22	0.16	0.14	0.35	0.24	0.20	0.26	0.15	0.27	0.39	X							
n	0.10	0.13	0.12	0.06	0.12	0.21	0.21	0.17	0.18	0.13	0.14	0.23	0.21	X						
o	0.35	0.33	0.22	0.08	0.15	0.30	0.20	0.32	0.24	0.15	0.15	0.35	0.30	0.17	X					
p	0.24	0.19	0.14	0.11	0.07	0.29	0.17	0.33	0.29	0.17	0.13	0.22	0.20	0.07	0.28	X				
q	0.17	0.22	0.13	0.04	0.08	0.26	0.19	0.31	0.21	0.14	0.10	0.25	0.21	0.13	0.28	0.15	X			
r	0.17	0.29	0.21	0.09	0.12	0.34	0.30	0.34	0.28	0.23	0.19	0.24	0.30	0.24	0.37	0.28	0.37	X		
s	0.18	0.12	0.15	0.16	0.10	0.30	0.14	0.27	0.21	0.13	0.14	0.27	0.19	0.13	0.32	0.23	0.21	0.25	X	
t	0.19	0.21	0.12	0.08	0.03	0.33	0.20	0.30	0.27	0.12	0.12	0.30	0.19	0.12	0.36	0.29	0.29	0.28	0.27	X

Key: a=tyrannosaurus rex, b=triceratops, c=stegosaurus, d=dimetrodon, e=apatosaurus, f=Michelangelo, g=Leonardo, h=Raphael, i=Donatello, j=April O'Neal, k=train, l=bicycle, m=motorcycle, n=aeroplane, o=boat, p=fly, q=spider, r=bee, s=grasshopper, t=butterfly

TABLE 10
Proximity matrix yielded by analysis of the recall protocols produced by the adults on L2

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
a	X																			
b	0.36	X																		
c	0.34	0.40	X																	
d	0.41	0.40	0.38	X																
e	0.36	0.35	0.30	0.41	X															
f	0.17	0.30	0.20	0.32	0.37	X														
g	0.19	0.21	0.25	0.24	0.25	0.27	X													
h	0.34	0.18	0.18	0.17	0.21	0.26	0.25	X												
i	0.19	0.32	0.40	0.42	0.37	0.48	0.42	0.40	X											
j	0.28	0.23	0.25	0.24	0.24	0.35	0.40	0.26	0.45	X										
k	0.22	0.34	0.32	0.32	0.33	0.32	0.23	0.22	0.41	0.27	X									
l	0.23	0.30	0.30	0.27	0.25	0.26	0.23	0.21	0.35	0.26	0.49	X								
m	0.11	0.35	0.23	0.30	0.25	0.26	0.21	0.24	0.37	0.22	0.41	0.40	X							
n	0.31	0.19	0.19	0.22	0.22	0.24	0.18	0.12	0.27	0.20	0.32	0.28	0.28	X						
o	0.39	0.36	0.28	0.32	0.41	0.48	0.31	0.25	0.46	0.39	0.53	0.43	0.41	0.35	X					
p	0.20	0.34	0.37	0.38	0.33	0.48	0.31	0.28	0.52	0.38	0.39	0.34	0.28	0.21	0.44	X				
q	0.36	0.25	0.26	0.24	0.24	0.25	0.22	0.25	0.37	0.24	0.31	0.29	0.27	0.16	0.29	0.43	X			
r	0.23	0.35	0.35	0.36	0.34	0.45	0.27	0.26	0.50	0.31	0.36	0.33	0.34	0.24	0.38	0.65	0.46	X		
s	0.26	0.27	0.29	0.35	0.32	0.42	0.26	0.27	0.45	0.29	0.36	0.35	0.30	0.28	0.37	0.56	0.43	0.58	X	
t	0.04	0.28	0.25	0.33	0.026	0.40	0.25	0.22	0.38	0.34	0.35	0.27	0.26	0.24	0.36	0.50	0.33	0.48	0.44	X

Key: a=house, b=hospital, c=school, d=church, e=castle, f=pig, g=sheep, h=cow, i=horse, j=goat, k=chair, l=table, m=bed, n=couch, o=lamp, p=apple, q=orange, r=pear, s=grape, t=cherry.