Developmental Constraints on A Theory of Memory

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The work presented in this thesis progresses along two related yet distinct paths, one associated with the development of a theory and the other with the development of the child. A model of human memory, based on the headed records (HR) framework, is first specified. This model is then applied within the area of event memory to explain memory phenomena in young children. The empirical work generated by the model shows that the limitations on children’s behaviour are mostly caused by performance rather than competence factors. First, it is demonstrated that the difficulties young children have in recalling specific events reflect a retrieval problem, which can be overcome with provision of specific cues, rather than, as it is commonly suggested, a problem with actually encoding the events. Second, children’s inability to recall false beliefs is shown to be associated with capacity limitations which lead to loss of a particular type of information - and not with the understanding of the concept of belief. The data show that the typical failure to recall false beliefs can be overturned by reducing the capacity demands of the task. In attempting to define further the role capacity limitations play in the loss of information, it was found that the order in which test questions are presented can determine what information is lost. This finding could only be accounted for by postulating two functionally independent on-line buffer stores. One of these is a limited capacity store containing simple structures which represent the current perceptual world and the other contains complex structures used in the interpretation of the contents of the former. Finally, the revised model is specified in sufficient detail to allow implementation. The computer simulation is then used to generate novel data patterns which are experimentally confirmed in further support of the dual buffer hypothesis.
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DEDICATION

This thesis is dedicated to the memory of Iftach Mor (2.4.1959 - 1.4.1987).
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1. PROLOGUE

1.1 Introduction

It is a commonplace to suggest that science progresses through debate between proponents of different theories. Whether resolution of a debate is achieved when one theory attains dominance over the other (Kuhn, 1962, 1970), or whether it leads to succession (Lakatos, 1978) or convergence (Laudan, 1986) of theories, would depend on the debaters' common language. Often, however, incommensurability (Kuhn, 1962, 1970) leads scientists to engage either in misdirected debates, or, what is worse, no debates at all. This chapter is about incommensurability and an example of its expression, and it describes a problem that had been a major obstacle and a great frustrator throughout the thesis. I am including this chapter partly to air this frustration, and mainly to explain my frame of work.

1.2 Incommensurability

Kuhn (1962, 1970) initially coined the term 'paradigm' to refer to a general theory, or more precisely a framework, that is used to describe a phenomenon within a given discipline. A paradigm, in this sense, not only provides a set of theoretical concepts but also includes instruction on how these concepts are to be applied and how the resulting data are to be interpreted. The applications of the general framework he termed 'exemplars' but he also referred to these as paradigms. Later in the thesis I will make a distinction between frameworks and 'exemplars' or in my terms 'models'.

Normal science, in his analysis, is characterised by the existence of one such paradigm that dominates within a discipline (e.g. behavioursim). During periods of normal science, the aim of scientists would be to extend the applicability of the general paradigm to nature. Most paradigms, however, reach a stage where unsolved problems begin to build up and anomalies (e.g. informed instructions, Brewer, 1974) begin to occur. When normal science reaches this point, a stage of crisis begins. This sees the emergence of new alternative theories (e.g.
cognitive) and leads to a stage of revolution and a struggle between the defenders of the old and proponents of the new. Resolution will be reached when one paradigm attains dominance over the other(s), and then normal science resumes. Kuhn's characterisation of normal science, and his ideas concerning the resolution of competition were the focal point of much subsequent controversy. First, however, it is necessary to define incommensurability which is a core notion in his analysis of resolution.

A fundamental part of Kuhn's view is the assertion that different scientific paradigms are 'incommensurable': there is no common body of neutral observation language which can be used to decide between two competing paradigms. The terminology used to express the assumptions, methodology and interpretation in one paradigm cannot be expressed in the terminology of another paradigm. More specifically, incommensurability arises when the reference of some term (e.g. definition, description) in a given paradigm is seen by a competing paradigm to refer to more then one distinct entity, or not to provide a reference at all; in other cases it may provide completely different references within each paradigm. For example, within cognitive development the terms competence and performance are used to refer to potential and realization respectively, whereas in other domains (e.g. linguistics) the same terms have been used inconsistently to refer to either potential or realization. The ambiguity resulting from this inconsistent usage of the terms is an example of incommensurability.

Incommensurability presents an additional and more fundamental problem: with no common grounds for comparison it may be difficult to decide when two paradigms are in fact competing in the same domain because each will offer a very different account of the domain for which it is a paradigm. For example, could autism be a subset of frontal lobe dysfunction? Is central coherence (Frith, 1989) the same as, part of, or different from SAS (Shallice, 1988).

Doubtless, questions such as these will ultimately be answered, but not necessarily in the way that Kuhn has suggested. He argued that, in the absence of common rational grounds for comparison, resolution of disputes could only occur through extra-rational means, specifically popularity. The paradigm that succeeds in recruiting more supporters to its camp will prevail - a solution that would appear to disassociate the notions of objectivity and rationality from the idea of science. A more scientific and rational criterion for evaluation of paradigms offered by Kuhn is their progressiveness: their potential to solve problems and extend their range of applicability. This, however, is a circular argument because by definition of incommensurability the problems faced by different paradigms are themselves paradigm bound and so would be their measure of progressiveness.
One of the principle criticisms of Kuhn's philosophy has been directed at his argument for a single dominant paradigm during periods of normal science. Science, as Lakatos (1978) pointed out, is rarely dominated by just one paradigm. Furthermore, competition between paradigms need not occur solely as a means of establishing the supremacy of one paradigm over others; on the contrary, Lakatos views such competition between paradigms as a dynamic, positive process which encourages developments within each paradigm. Developments like that often consist in a succession of theories, whereby new theories replace older ones while preserving their more important features. For example, this process of development through competition was evident in the imagery/propositional debate. Although the competition itself seemed to have ended in a 'draw', the debate itself yielded a set of highly imaginative experiments and saw the creative formation of theories and their evolution at different stages of the debate (e.g. from Paivio's (1971) dual system to Kosslyn's (1981) computational model incorporating a mediating spatial buffer).

A somewhat more finely tuned model for the process of evolution of theories was put forward by Laudan (1986). Laudan made a distinction between the empirical and the conceptual elements of a paradigm, allowing a paradigm to evolve in either of these spheres. Laudan's account departs from that proposed by Lakatos in that it allows for basic, conceptual assumptions to be changed - if found inadequate - without necessitating dismissal of the paradigm itself. Thus, the basic 'black box' assumption at the core of earlier learning theories has been replaced by a more cognitive approach. However, the earlier S-R methodology still remains in its original form. The conceptual/empirical distinction also allows resolution of competition to take the form of convergence between paradigms as well as of succession within a paradigm. For example, while the Gibsonian conceptual framework (based on direct perception) has been dismissed, Gibsonian (1979) principles (e.g. optic flow, texture gradients), have been adopted and combined with Helmholtzian (1886) processing philosophy in modern computer vision.

The evaluation of competing paradigms is of the essence in both Lakatos's and Laudan's accounts. However, if evaluation is to be constructive in the ways they have suggested, then it is necessary that incommensurability is overcome. Neither succession nor convergence of theories would be possible if a debate takes place in a tower of Babel. When this is the case, then debates will be incoherent and, as Kuhn argued, science may have to resort to extra-rational means, or simply stand still. The debate over the role of meaning in
Prologue

children's memory (Istomina, 1975; Schneider & Brun, 1987; Weissberg & Paris, 1986) is an example that illustrates Kuhn's point.

1.3 Incommensurability and Istomina's study

Istomina (1975) focused the attention of developmentalists on the role of meaning in remembering. She proposed that remembering during preschool years is embedded in activities that are meaningful to the child - meaningful in the sense of functional and goal directed activities such as exploration and play. In her study, Istomina compared young children's memory performance in two alternative settings: a 'lesson' setting and a 'game' setting. The 'lesson' setting involved a simple presentation of a set of to-be-remembered words; in contrast, the 'game' setting embedded remembering in a complex game in which the children (six at a time) were given a role to play in either a nursery or a store setting. During the course of play, one of the nursery 'actors' was asked to go to a simulated grocery store and buy items that were needed for the nursery. The experimenter named the items and provided a permission slip, a basket and money with which to buy the items. The game continued until all children playing in the nursery setting had been to the store.

Istomina hypothesised that performance in the context of a 'game' activity would be better than performance in a 'lesson' activity because the game provides a meaningful goal for the child. Remembering in a 'game' condition would be essential for the purpose of carrying out the play activity, whereas in the context of a 'lesson' activity remembering has no purpose other than remembering for memory's sake. Consistent with her prediction Istomina found that 4-year-olds demonstrated greater success in voluntary remembering in the meaningful 'game' setting.

Weissberg and Paris (1986) pointed out several methodological problems in Istomina's study which their replication aimed to correct: (a) the order of activities was not counterbalanced; (b) the lists were different for the two conditions; (c) no statistical analysis was conducted. In addition to improving on these weaknesses, Weissberg and Paris also introduced an additional 'party' setting and its counterpart 'lesson' condition. In this new 'party' setting children were required to recall the first names of six stuffed animals for the purpose of introducing them to a seventh stuffed animal in the context of a party. In the 'store' setting the children were presented with a list of food items, given pretend money, and a shopping basket, and then sent to a simulated store to make the purchase. Weissberg and Paris (1986)
reported better performance in the lesson condition than in the play activity, and better recall for food items than for names. Weissberg and Paris concluded that "global motivational dispositions" do not account for contextual difference in children's remembering. The poorer performance in the 'game' conditions they attributed to distractions involved in a play situation.

A second replication was carried out by Schneider and Brun (1987). These investigators noticed that the presentation procedure in Istomina's study was not standardised. Some children, particularly in the game condition, asked the experimenter to repeat the list of items. Therefore, the argument goes, the improved performance in this condition could have resulted from the additional exposure to test items. In addition to standardising the presentation procedure, Schneider and Brun also corrected the shortcomings already pointed out by Weissberg and Paris (1986). The 'game' setting in this experiment was similar to the setting used by Weissberg and Paris. This second replication revealed no differences between the 'game' and 'lesson' conditions. The authors concluded: "...there is no reason to assume that presenting the items in the context of play or lesson activity would make a difference in the direction that Istomina expected" (p, 340). Table 1.1 summarises the findings from the three studies.

<table>
<thead>
<tr>
<th></th>
<th>STORE game</th>
<th>STORE lesson</th>
<th>PARTY game</th>
<th>PARTY lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Istomina (1975)</td>
<td>2.00</td>
<td>1.05</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Weissberg &amp; Paris (1986)</td>
<td>2.35</td>
<td>2.75</td>
<td>0.6</td>
<td>1.25</td>
</tr>
<tr>
<td>Schneider &amp; Brun (1987)</td>
<td>2.08</td>
<td>1.59</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

These three studies have produce three feasible, but conflicting outcomes. Is it possible, then, to conclude anything about the role of meaning in children's memory? Clearly not, at least not without looking closely into each design to identify the origins of these variations.

In accord with Laudan's distinction, two independent factors played a part in producing these discrepant results: the empirical and the conceptual. At the empirical level,
methodological differences, independent of the theoretical motivation for the particular design, were responsible for part of the discrepancy. At the conceptual level, the discrepancy is most likely due to differences in the understanding of the term meaning.

With respect to empirical matters, the methodological shortcomings of Istomina's study have already been mentioned and therefore do not require further discussion beyond the assertion that such problems can indeed invalidate the results of any study. However, the methodological consequence of the additional party theme in the Weissberg & Paris (1986) study should be pointed out. In the party setting the children did not only have to remember six names but also had to remember six new name-animal associations. The informational load in the 'party-game' activity, therefore, would have been greater than in the 'party-lesson' activity. The same argument applies to differences in informational load between the 'party-game' and 'store-game' conditions. It should not be surprising then, that children generally performed better in the lesson context of the party theme; or that they recalled more food items than names. If the data concerning the party theme (see table 1.1) were excluded from analysis, it is doubtful that an analysis of the 'store' theme alone would have produced significant differences between its game and lesson counterparts. Thus, the differences between Weissberg & Paris (1986) and Schneider & Brun (1987) results was most likely a consequence of this methodological variation as it was the only important difference between the two studies.

A further methodological difference between Istomina's study and its replications, concerns the subtle but perhaps important difference in the way in which the game task was engineered in the different studies. In Istomina's study the memory task was part of a 'make-belief' activity that the children took part in. The memory goal was embedded in the task of buying, which in turn was functional in the context of the child's role in the game. Children who could not remember the shopping list would have compromised their subsequent participation in the game. Thus, the memory goal was an essential means to another goal - carrying on with the game. In contrast, the game in the replication studies did not require subsequent participation in a pretend game. The child was not given a role to play, there were no other children present, the memory goal was embedded in the buying of the groceries, but it had no function beyond satisfying the experimenter. This lack of either a real or pretend purpose could account for the differences between the replications and Istomina's findings (I will discuss this point more fully in the next section).
Assuming that the researchers conducting the replications did read Istomina's detailed description of her procedure, the only explanation for their failure to replicate the study in the spirit that she had intended is that their understanding of what constitutes a meaningful activity differs from that of Istomina's. Thus, the methodological variations in this case are a manifestation of a conceptual separation between the two camps. The problem, however, goes beyond methodology. The problem, as Kuhn described it, arises in the interpretation of results and the subsequent conclusions. If there is no common understanding of the term meaning then any discussion contrasting Istomina's position with one's own opposing position becomes incoherent. The only possible claim that Weissberg & Paris or Schneider & Brun could advance is that in their particular meaningful setting, there was no advantage of play over lesson; neither however, could extend this claim to a refutation of Istomina's hypothesis since her idea of meaningful setting was different.

This is what Kuhn meant by incommensurability and, as he claimed, it is (still) very much a part of science. Arguments concerning issues such as the role of meaning in children's memory, the use of strategies, or deliberate remembering, may promote theoretical progression in accordance with Lakatos and Laudan's proposals only when scientists agree on the terms they are using. But, as the example demonstrates, when terms such as "meaningful activity", "context" and "motivation" are used differently by those interested in the qualitative aspects of memory and those interested in the quantitative ones, the contradictory outcomes that are likely to ensue would undermine the potential for progression, since any possible interpretation can now be legitimately supported by 'objective' observations.

1.4 Is Incommensurability Inevitable?

Istomina's study and its replications reflect Kuhn's notion of incommensurability. However, his assertion of incommensurability as an inevitable consequence of scientific change (and multiplicity of languages/theories) is debatable.

One argument against the idea of incommensurability is the observation that a history of science is indeed possible. If earlier theories are expressed in languages that are incommensurable with current language, how can the historian understand those theories and describe them in a way that will be understood by current readers? (Carey, 1991). Equally, if incommensurability is a problem to the extent that Kuhn suggested it is, then not only would the history of science be incoherent, but also training of new scientists would be extremely
difficult. Clearly, as Kitcher (1988) points out, communication is possible between two parties if one can work out what the other is referring to and if the two share some common language. Even for terms which mismatch, there is still some overlap, so that in many contexts the terms will have the same reference. Indeed, that two speakers could learn each others' language and reach an agreement on reference of terms has been demonstrated by Morton (1974). In an article on the use of concepts, he disambiguated the competence-performance distinction such that linguists and psychologists could share the same understanding of these terms. Why then is incommensurability still a fact of science?

In my view (and I rule out lack of motivation) it is generally the case that where incommensurability exists, it is a consequence of the underspecification of terms, or of theories and their assumptions. Although there is a large degree of correspondence between definition of terms and specification of theories, I would, nevertheless, like to distinguish between two independent factors that breed incommensurability. The first can be traced to ambiguities associated with the use of linguistic terms (e.g. meaning) as theoretical constructs independent from a theoretical framework. The second factor for potential ambiguity is when a term is defined in the context of a theory but the theory itself is underspecified, for example the concept of *representational change* in Gopnik's and Astington (1988) account of young children's theory of mind.

The first issue - the use of linguistic terms as theoretical constructs - is particularly problematic for psychological research since much of the terminology is borrowed from everyday language. Expressions such as meaning, context, and motivation have become an integral part of our terminology, yet they often remain scientifically non-definitive. Usually in such cases, the lexical meaning of the word is borrowed and used as a proxy for a theoretical entity. Theoretical entities (e.g. that which *meaning* is suppose to describe), however, can only emerge from within theories not lexicons. Therefore, if an everyday linguistic expression, such as *meaning*, is to be useful theoretically, its meaning must be derived in the context of a theory, not in the context of an individual's lexical competence. Otherwise, as the example of Istomina's study demonstrates, the theoretical meaning of *meaning* would vary with each subjective understanding of that word's lexical definition. Thus, if *meaning* is to be a useful theoretical construct with which to explain and predict memory phenomenon, it must be translatable into a meaningful memory mechanism.

For example, *meaning* may refer to the contents of records (i.e. long-term structures) which help organise the input information into higher level structures. In this context, *meaning*
would be associated with the activation of the propositional system and the use of records (Morton, Hammersley & Bekerian, 1985; Norman & Bobrow, 1979) for interpretation, whereas 'meaningless' would be associated with short term phonological processing which involves no interpretation and no records. Thus, a familiar elaborate activity is meaningful because it is more likely to mobilise a propositional system, and a list of words which is more likely to mobilise a phonological system would be meaningless. However, there are no hard and fast rules. It is certainly the case that tasks that appear to require similar type of processing could nevertheless activate different memory systems. For example, Baker-Ward, Ornstein and Holden (1984) observed children perform poorly on a task which required them to memorise a set of toy objects. On the other hand, these very same children showed excellent memory for the names of several classmates in the order in which they were scheduled to appear in the testing room. Although both these tasks are characteristic of short-term memory tasks, the latter was most likely to have activated the propositional system and to have utilised records of previous experiences. For example, children remembering that Jo who is always first to do things in class was last this time and that Bill was first. The game activities in the replications studies could have been similarly deceiving, for although a propositional system may have been mobilised at some point during the activity, the target information itself could, nevertheless, have been encoded phonologically. I believe the target information in these studies was encoded phonologically because the initial setting of the games did not establish a meaningful context (i.e. trigger a record) prior to encoding of this information.

Whether or not a meaningful context is established would depend on how the underlying 'shopping' event representation is organised, and on how the shopping activity is related to this representation. We know that children organise events around main acts, therefore the presence or absence of such acts in a given setting would be crucial for interpretation as it could determine whether an appropriate reference record is triggered. Since the record provides the meaningful context which is to assist encoding, the presence or absence of a relevant event act, prior to encoding, would be instrumental in deciding which processing system is to compute the target information. In Istimina's study, children set up a kitchen in which a 'cook' (one of the children) was about to prepare lunch, then a child was sent to a simulated store to purchase a few items for the kitchen; in the replication studies the experimenter told children that they were about to play a game, then a child was asked to buy a few items from a simulated store. Thus the initial setting in Istimina's study set-up a goal (prepare lunch) which was directly relevant to the underlying representation (e.g. a shopping
event representation) that was to render the activity (of buying the items) meaningful, and to assist encoding of the target items. There was no initial setting in the game activities of the replication studies that could help set-up a goal for a shopping event, prior to presentation of the list, and this way render the list meaningful in the context of a familiar (event) structure. The absence of meaning during encoding of the list would mean that the target information in the replication studies was most likely to have been encoded by the same system that processed the list of items in the context of the lesson condition - the phonological system. It may be the case that a shopping event representation was subsequently triggered, once the money and the basket were introduced into the game, but by that time the crucial information would have already been processed.

The game activities in the different studies differed on this and other dimensions precisely because there was no consideration of the mechanisms that make a familiar activity meaningful in the context of the memory system. Neither Istomina, Weissberg & Paris or Schneider & Brun had a theory of memory with which to justify their design or interpret their data. In all studies the design and interpretation were based on some intuitive understanding of the concept of meaning. This is clearly insufficient. It is only a theory that provides the language with which to make such discussions coherent. Only then can the differences between meaning and meaningless, game and lesson, or even game and game become tangible.

Having a theory, however, is not enough. In order for the theory to be useful, that is, accessible and commensurable (as well as falsifiable and predictive although I am not discussing these two issues here), the theory must have a clear set of assumptions that could be understood by those who might be interested. If, however, the theory’s set of assumptions is incomplete or ambiguous, then the theoretical concepts these assumptions are meant to define will themselves be ambiguous and therefore incommensurable. The concept of representational change in Gopink and Astington’s (1988) account of young children's theory of mind is one such example. In chapter 6 I will discuss theory of mind and representational change in more detail. For the present, however, I simply wish to illustrate my point about underspecification with an abstract from Astington and Gopnik’s paper in which they introduce their notion of representational change:

"... We might capture this fact by saying that as adults we have representations of objects in the world, that those representations change, and that we represent the fact that those representations change. All creatures that represent the world at all change those representations. However, human adults have the additional ability to
represent their past representations of the world and to contrast them with their present representations. They can understand the processes of representational change itself. (Gopnik & Astington, 1988 p. 26).

The most fundamental confusion in this abstract is between structure (of representations) and process (operating on representations); representational change, as defined, encompasses both. It is used to refer to changes in the contents of existing representations (structure) as well as to representation of changes (process). This is further compounded by the contradictory manner in which the authors conceptualise the essence of the actual change. On the one hand, it is the case that existing representations change. On the other, existing (unchanged) representation are compared to present representation. Suppose representational change is associated with structure then it is either the case that something changes in the contents of existing representations, or, if existing representations don't change, then it is the differences (or changes) between past and present representation that are uniquely represented. I do not wish to argue for or against any particular choice, but whichever it is, it can certainly not be both. But, in order to decide between the two the authors must first clarify their concept of 'representation'. Alternatively, if representational change is viewed as a process which either introduces changes to existing representations, or detects, and possibly represents, the differences between representations, then the ways in which this process may be different from any other representing process that routinely computes information must be specified. At the existing level of specification, however, the concept of representational change is nothing less than incommensurable. And this is not because it might be understood to refer to different entities by virtue of being expressed in the terminology of a particular paradigm, but because, by its own underspecified definition, it is referring to different entities.

Thus, incommensurability is still about differential understanding of terms, but it is not, as Kuhn suggested, because the terminology associated with a particular language (paradigm or a theory) is inherently inaccessible to other speakers. The terminology that is used to express the assumption in a given paradigm can be learned as long as there are assumptions (theory) to learn and as long as these assumptions are themselves clearly defined. Incommensurability arises when the set of assumptions is underspecified (e.g. representational change), or when the terminology replaces the assumptions (e.g. meaning). It is the set of assumptions that generates, or at least should generate, the terminology - not the reverse. Therefore, if terms are incommensurable it is the set of assumptions that is at fault not the terminology.
So is incommensurability inevitable? I would say not. In my view, incommensurability is not, as Kuhn suggested, an inevitable consequence of scientific change, but rather an inevitable consequence of underspecification, and therefore it can, and should be, avoided. To a large extent, this is what my thesis is about. It is about theory specification as much at it is about young children's memory for events.

1.5 General Approach

In this thesis I have worked towards specifying a model of memory based on Morton, Hammersley and Bekerian's (1985) Headed Records (HR) framework. Event memory is the specific exemplar to which the model is applied. Specification is generally about constraints, and my work involved the application of two different procedures each bringing its own set of constraints - developmental and modelling.

**Developmental constraints**

Children, like amnesics, have a simplified memory system, in their case not resulting from damage but rather due to a relatively restricted knowledge base and lack of development of domain specific functions. As the child's memory system is similar in kind to that of the adult, these restrictions mean that children's recall performance more closely reflects the underlying structures. The empirical work that is reviewed in Chapter 2 will reveal the similarities as it will reflect the differences. It will show that, like adults, young children's accounts of events exhibit many organisational characteristics of scripts, including generality, sequentiality and agreement on main and central acts, yet, these accounts are of generalised knowledge, and not the autobiographical recall of specific experiences; the ability to recall specific events appears to be restricted in young children. Young children's memory system then, while similar in many ways to that of the adult's, will vary along certain dimensions. In Chapter 3 I will introduce a model of memory based on the HR framework, and in Chapter 4 I will specify developmental aspects of this model that would account for such variations. My conclusions will be that by the age of 3 the basic functions of the memory system are already in place, although they still require some fine tuning. The experimental work that is reported in Chapters 5 to 7 will provide evidence in support of this conclusion. It will show that whatever the limitations are on the memory system they are performance rather than competence limitations which can be overcome with a little support for the environment. Children's typical failures and, in particular, the environmental support that is required to
correct them are the crucial factors which bring us closer to an understanding of the workings of the memory system as well as of the development of the child herself.

*Modelling constraints*

While development constrains the problem domain (i.e. the memory system), modelling constrains the solution (i.e. the theory). One of the advantages of modelling is that it explicates the relationship between different parts of a theory which are easily lost in the abstraction of language. We can define theoretical constructs and express some of the relationships between them semantically, but it is only when these constructs are integrated into a single structure (a model) that contradictions, ambiguities and/or incompleteness become truly obvious. In addition to exposing such inconsistencies, modelling, and in particular computational modelling, can also go some way in suggesting the solutions. The HR model (Chapter 3) was constructed with these objectives in mind. It integrates the HR framework's basic assumptions into a single structure, and expresses the relationship between the different theoretical entities that are defined within the framework. This model was further developed in the course of the thesis (and in light of the data) to reach the necessary level of specification for implementation. The implemented model will be outlined in Chapter 8.

Computational modelling has been often criticised for its predisposition to confuse methodological ('engineering') solutions with theoretical ones. This is not surprising given that the majority of computational work is usually designed to test a particular theoretical model, but experimental studies are rarely designed to test the assumptions that the simulation program implements. This failing can be avoided if experimental work is specifically carried out to test the program's specific assumptions and predictions. By the end of the thesis I hope to have made the first steps towards achieving this aim.
2. YOUNG CHILDREN'S MEMORY FOR EVENTS

2.1 Introduction

Memory for events plays a central role in early development. Preschoolers must rely on their experiences and their memory of these experiences to acquire knowledge, as other means of learning during this time are largely unavailable to them. Yet, until relatively recently, the Piagetian view of the child as being "memory deficient" was widely accepted. It was not until a theoretical shift towards socially and contextually oriented approaches to development and a corresponding shift away from laboratory settings towards more ecologically valid assessments, that the richness of young children's recall was revealed. The picture that has been emerging is of a 'young' system that qualitatively resembles the final adult product. By the age of three children already show the same overall form in their account of scripted events as do adults: they can recall event sequences in correct order, emphasize the central actions, and even use the correct verb forms of the timeless present. Still, these reports are of general knowledge, not the autobiographical recall of individual events. As far as recall of their personal past is concerned, young children are largely silent.

Children's tendency to default to generalised descriptions when asked about specific events is a well established finding in the literature. A series of studies carried out by Nelson and her collaborators have shown that when children are asked questions like "Tell me what happened when..." they do not refer to specific events but instead tend to report the events in general and abstract terms. For a time, this was thought to indicate a general inability to attend and to encode any specific event details that do not conform to a stringent generalised structure. However, a number of recent studies (Hamond & Fivush, 1991; Price & Goodman 1990) have shown that if presented with the appropriate cues children can and do remember detail with surprising accuracy. The status of specific episodes in the overall schematic structure consequently became crucial for completeness of explanation. In this and the following chapter, I will examine the explanations offered by various frameworks to account for young children's memory for events, focusing on the apparent differences between quality
of recall of specific events and general event representations. I will first discuss the structure of a script, and then outline the two main theories within the developmental literature: the GER model (Nelson, 1979, 1981, 1986) and schema confirmation/deployment theory (Farrar & Goodman, 1990).

### 2.2 What Is a Script?

A script (Schank & Abelson, 1977) is a special case of a schema representing abstract and general knowledge about routine, real life events. Bartlett (1932) introduced the 'schema' into the psychological literature in the sense of an active organization of past experiences. Bartlett emphasised remembering as "a matter of social organisation", moving away from the notion of memory as a pure process that can escape the influences of knowledge and experience. Similar past experiences are organized as general schemas. These schemas guide our perceptions and interpretations of events and in turn are altered and adapted to incorporate new information. Following Bartlett, current schema theories use the term schema more generally to refer to abstract knowledge structures implicated in a broad range of knowledge domains and a variety of cognitive functions. Thus, in addition to their role in organisation and comprehension of episodic information, schemas also guide retrieval, play a role in the execution of actions, and are used as frameworks for solving problems in a variety of domains, e.g. linguistic schemas, cultural schemas etc. A script then, is a schema whose knowledge domain involves routine, real life events. A script can be generally characterised as a sequence of causally-temporally linked elements that are hierarchically organised around a specific goal.

#### 2.2.1 Event Goal

The goal constitutes the main act of the event around which event elements are organised, for example, 'eating' would be the goal in a lunch script. The goal is the most commonly reported act in children's recall (Nelson & Gruendel, 1981). Although there is general agreement within the same age group about what constitutes the goal of an event, research has shown that the assignment of centrality to an act changes with development (Fivush, 1981; Gruendel, 1980). Gruendel (1980), for example, interviewed children about 4 different events (birthday party, planting a garden, making cookies and building a campfire) and then measured performance in terms of frequency-of-mention of acts. She found that high-mentioned acts (acts mentioned by 90% of children) occurred for only two of the events
for 4-year-olds, three of the events for 6-year-olds, and for all four events for 8-year-olds. Looking at the degree of match between designated goal and high-mentioned act, Gruendel found no match for 4-year-olds, a match for two events for 6-year-olds, and a 100% match for 8-year-olds. The increase in intergroup agreement and degree of match as a function of age may suggest that at a younger age children do not organise the event around the same goals as do older children and adults. The degree of match may depend on the meaning and relevance of the event to each particular age group. For example, the main goal in a restaurant script may be set as 'eating' in a child's script and as 'going out' in that of an adult's; going to McDonald, on the other hand, may have quite the reverse meaning for the two age groups.

Whether an event goal is their own or whether it is shared with adults, there is evidence to suggest that pre-school children are aware of it (Hudson & Nelson, 1983). In a study on story recall, Hudson and Nelson (1983) presented children with two stories about a birthday party. In one condition children were told the goal in the opening statement of the story "One day it was Sally's birthday and Sally had a birthday party", and in a goalless condition this statement was replaced by "One day Sally was waiting by the window and looking for her friends". Children were read the story and were then asked to recall it. They were also asked to give a title to the story as a way of determining whether they had perceived the goal. The amount recalled was the same in both conditions, indicating that children were not affected by the goal or that the goal did not direct their recall. However, when asked, all children could tell what the goal was, and 50% of children in the goalless condition spontaneously included a goal statement in their recall. Thus, even when the goal is not explicitly stated, young children are nevertheless aware of it, possibly because their underlying script structure, a birthday party in this study, is organised around a goal.

2.2.2 Component parts

A script contains actions, actors and props that are appropriate to a particular spatial-temporal context. These elements are used to achieve the goal. A script, however, does not necessarily specify particular elements, instead it defines the appropriate slots and a set of requirements on what can fill those slots. Default values for these slots will be assumed, if the person, action or object are not specified (Mandler, 1979). Any of the default variables which are expected to occur within a script representation, exist at a global cultural level, and are imported into the particular event representation. For example, sex roles in a garage script -
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on a first visit to a garage one would expect the mechanic to be a male and the receptionist a female.

Of the different event components, actions are remembered better than objects both in young children (Fivush & Hamond, 1989) and adults (Cohen, Peterson & Mantini-Atkinson, 1987), and atypical actions are remembered better than typical ones (Davidson & Hoe, 1993; Maki 1990; Nakamura, Graesser, Simmerman & Riha, 1985). Reaction times to recognize whether an action was or was not stated in a scripted activity are faster for atypical than for typical actions (Nakamura & Graesser, 1985, with adults), although initial processing of atypical actions is slower (Bellezza & Bower, 1981). In addition, memory discrimination is better for atypical than for typical actions, with discrimination of very typical actions being extremely poor (Graesser, Woll, Kowalski & Smith, 1980). However, atypical actions do not uniformly produce better recall. Atypical actions that disrupt the completion of event goals are better remembered than those atypical actions that are irrelevant to the goal. Both adults (Bower, Black & Turner, 1979) and children (Hudson, 1988) recall disruptive atypical actions better than irrelevant ones. Both types of atypical actions, however, are equally well recognised (Hudson, 1988).

2.2.3 Temporal Organisation

Temporal organisation specifies the order of occurrence of event components, indicating their relative position within the sequence. Two factors affect the temporal structure of a script. One is the temporal variance or invariance of the event, and the other is the type of links that join event items together.

If components of a given event sequence occur in a fixed order, then that event sequence is said to have a temporally invariant structure. If, on the other hand, components of a sequence can occur in any order then the sequence has a temporally variant structure. For example, in a dressing-up script, a link between socks and shoes will be temporally invariant, whereas the link between shirt and trousers will be temporally variant. Temporally invariant sequences that are not causally linked, are usually dictated by social-cultural convention, e.g. paying is the last act in most restaurant scripts and first in fast-food restaurant scripts. Among acts that are temporally related, invariant relations are much more frequently represented than variable ones (Hudson & Nelson, 1983; Slackman, Hudson & Fivush, 1986). Temporal invariance plays an important role in guiding young children's recall. When asked to recall
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misordered events, 4-year-old children make corrections in memory that preserve the canonical (right script sequence) order of the event by omitting the misordered act; 6-year-olds, on the other hand, transform statements to make them accord with the logical sequence. This tendency to correct temporal violations, has been suggested to indicate that the internal representations of younger children are more rigid, and that generally, younger children are more dependent than older children on temporal invariance (Hudson & Nelson, 1983).

In addition to their temporal order, scripts are also characterised by their spatial-temporal links and causal-enabling links. Spatial-temporal links refer to changes in the location of event actions. This type of connection can be either invariant or variant, i.e. event sequences unfolding in the same location, or in a number of different locations. Spatial-temporal links are the most common type of link between acts that are found in 3- and 4-year-olds' reports of events (Fivush, 1984; Nelson, 1979).

A causal relation exists when the occurrence of one item in a sequence is either a consequence of a preceding item, or is dependant on the occurrence of another item in the same sequence. Although the latter type of causal relation may be more properly described as enabling, the term 'causal link' is commonly used in the literature as an umbrella term to refer to both types of links. Causal-enabling links are by definition invariant, however, it is not necessarily the case that temporally invariant relations are always causal. For example, in the 'undressing' script taking off shoes enables taking off socks, thus the relation between shoes and socks is enabling; it is also temporally invariant. However, in a 'dressing-up' script, the link between shoes and socks will be temporally invariant, not causal, because shoes can be put on with or without socks.

Causal links, too, play an important role in young children's recall. Causal links are evident at an earlier age than are simple temporal links (Nelson, 1979; Nelson & Grundel, 1981). Preschoolers, as well as older children and adults, recall causal relations more readily than they do other aspects of an event (Bauer & Trevis, 1993, Hudson, Fivush & Keubli, 1992; Hudson & Nelson, 1983; Price & Goodman, 1990). This is true for the total amount recalled as well as for order recall. The advantage in recall of causally related sequences is apparent after a single experience with an event (Bauer & Mandler, 1989,1992; Hudson, 1986; Slackman & Nelson, 1984; Smith, Ratner & Hobart, 1987). For example, Bauer and Mandler (1989, 1992), using elicited imitation tasks, observed a well-ordered recall of both familiar (e.g. give teddy a bath) and novel (make a rattle) sequences in 11.5- and 16-months-old infants. Their
Young subjects imitated more accurately sequences that were causally linked than sequences that were ordered arbitrarily. Moreover, order recall of causally linked novel sequences was either the same or better than that of familiar sequences. The advantage of causality over familiarity may suggest causal links as the basic building blocks of event representations. I will discuss this point in Chapter 4.

Bauer (1992) sought to identify the source of the advantage afforded by causal-enabling relations. Causal relations, she reasoned, appear to reduce the mnemonic demands associated with remembering events, and she suggested that there are two ways by which a reduction in memory load could be achieved. First, a causal relation may allow one to infer temporal order rather than remember it. If this is the source of the advantage, then subjects who are presented with an end state of a sequence would be able to infer the preceding steps that led to it. Second, a causal relation may have the advantage of chunking separate elements into a single organizational unit. If this hypothesis is correct, then elements of a causal sequence will be resistant to separation by other elements. Using elicited imitation of novel action sequences with 20- and 25-month-olds, Bauer obtained support for the chunking hypothesis, but no evidence in support of the inference hypothesis. The children were very rarely able to generate sequences based on information about the end state of a sequence, but, they did demonstrate a strong resistance to separation of causally linked items. They systematically displaced interrupting elements (elements inserted within a causal sequence on presentation) such that the temporal order of the causal sequence was re-established. This was true irrespective of whether the interrupting elements were relevant or irrelevant to the event as a whole.

Note, however, that the children in Bauer's study were very young. It may be that the general processing and inferencing abilities at this age are not sufficiently developed to support successful performance on the tasks Bauer was using. For example, one of the tasks in the study involved making a rattle by putting a rubber ball in a larger cup and then inverting a smaller cup into the larger one. In the 'end state' condition the experimenter modelled *shaking* the rattle, then dismantled the rattle (out of sight) and provided the children with the props, encouraging them to make the rattle. Thus, rather then infer a cause from an effect, children were to work out the steps leading to a solution of a 'making the rattle' puzzle on the basis of the puzzle's final solution, i.e. the completed rattle. This is more a general problem solving task than an inferencing task, and it may have been too difficult for young children to resolve.
After all, we all know the final solution of a Rubik Cube, but how easy is it to actually reach this solution?

Further, the majority of links in Bauer's event were not causal but enabling. It was not the case that the creation of the rattle caused the rattle to shake. The experimenter's movements caused the rattle to shake. Making the rattle (putting a ball in a cup and securing it with another cup) enabled the experimenter to cause the rattle to shake. Even the links within the 'rattle making' event are enabling. The physical constraints force a fixed temporal sequence, but there are no cause-effect relationships within the sequence. Thus, it may be that the ability to infer from the end state is restricted to cause-effect relationships, whereas enabling relationships have the advantage of chunking event items together. Temporal invariance may have an advantage for similar reasons, i.e. chunking. The difference between the two, however, is that chunking afforded by temporal invariance is imposed by conventional constraints and must develop over time, whereas chunking in enabling links - being imposed by physical constraints - is inherent in the structure.

In general, causal-temporal links mark the difference between weak scripts, specifying the components but not the order in which they occur, and strong scripts in which those links are specified (Abelson, 1981).

2.2.4 Hierarchical structure

The elements of a script are organised hierarchically from goal to filler items, with information of a more specific nature embedded under nodes containing more general information. A script is typically depicted as a tree structure consisting of alternative paths that may be taken under different circumstances. For example, a restaurant script may embed a number of scripts (branches in the tree) each specifying a different type of cuisine, e.g. a French restaurant, a fast-food restaurant etc.. Each of these embedded structures will have its own organizational properties. At the higher levels of the hierarchy, information is general with no specification of detail. As one moves down the hierarchical structure, information becomes more detailed and more specific to particular script instantiations. For example, the fast-food-restaurant branch will include more detailed specifications than the general restaurant script, and these specifications will differ from those specified within the French restaurant branch.

The acts most commonly used by children are identified as main acts (Nelson, 1979; Smith, Ratner & Hobart, 1987). Of these, the central acts (goal and the final anchor act) are
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mentioned most frequently (Fivush, 1984; Gruendel, 1980). When probed, children in these studies showed knowledge of variable acts and items either as lists of possible actions or else as an action sequence. This is suggestive of a common underlying structure in which there is a basic level of temporally organised main acts that stand in hierarchical relation to other acts or props. In another study, McCartney and Nelson (1981) found no difference in the number of main acts recalled by younger and older children. However, older children in their study recalled more filler items than younger ones. Although this may indicate a gradual development of a hierarchical structure, a lack of correspondence between young children’s internal representations and their verbal reports cannot be ruled out. Furthermore, since the aforementioned studies examined hierarchical organization of routine events, it is not clear whether such organization develops over time or whether it is in place after a single experience.

Ratner, Smith and Padgett (1990) examined hierarchical organisation in children’s and adults’ recall of a novel, clay-making, event. The actions composing the event were organised into 5 superordinate categories (getting ready, adding dry materials, adding liquids, mixing and cleaning-up). Each of these categories consisted of 6 subordinate actions. The subjects participated in the event and were then asked to recall it under one of four cuing conditions (no-cue, goal-cue, superordinate-label-cue, subordinate-action-cue). Since the cues were taken from different levels in the hierarchical tree, performance was expected to vary as a function of cue type if hierarchical organisation was present. No strong evidence of hierarchical organisation was found. There were no differences in recall between the cuing conditions within the same age group, although adults provided more information than children. Cuimg, however, influenced the way the event was recalled two weeks later. This was true for both age groups. No cues were provided in the delay recall condition, yet subjects whose immediate recall was directed by a cue, recalled the event in the same order rather than in an order corresponding to the immediate no-cue condition. For example, children in the subordinate-cue condition (last action in dry materials) started their recall reporting the actions from the category immediately following this action (liquids category), whereas children in the other cue conditions started their recall by reporting actions from the dry materials category. Two weeks later, with no cues, the children’s recall preserved this initial structure. This illustrates the effect of recall on the general organisation of the underlying representations. Specifically, a memory representation of the 1st recall session (which I will later refer to as a secondary record) was formed, and it was this representation that children were addressing in their 2nd
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recall session rather than a representation of their actual experience (or their primary record). I will return to this point in Chapter 5.

In a follow-up study, Ratner et al. (1990) examined hierarchical organisation in a picture sorting task. Following observation of the clay-making event, subjects were asked to sort pictures of the event and were then asked to recall it. Recall in this study was cued by the different superordinate labels, that is, cues were all taken from the same level in the hierarchical tree. In the sorting phase, the children sorted the pictures into more groups than did adults; they also organised the groups along different dimensions in comparison to the adults. Children often organised groups around objects, whereas the adults used superordinate labels and actions in their organisation. In subsequent recall the children reported more items in the get-ready-cue and the liquids-cue conditions then they did in the no-cue condition. The other cue conditions (dry and mix) did not lead to an improvement in performance. The adults’ recall was at a ceiling for all cue conditions (fewer actions were used in this study then in the previous study). The authors concluded: "The fact that two of the cues were effective in the present study, confirms that superordinate category labels did organize some of the subordinate actions......it is also clear that both levels were not entirely integrated." (Ratner et al., 1990, p. 78). It is not clear however, why Ratner et al. did not use children’s sorting categories as cues for recall: if children organise events along different dimensions than do adults, why use adult organisational labels as cues for children’s recall?

In addition, the authors did not report in either study, whether between-category intrusions occurred in the order in which items were recalled. Hierarchical organisation should lead to categorical sectioning in recall, i.e. recall of items associated with a given superordinate branch should be exhausted before items from another branch are recalled. Thus, order analysis may have provided some insight into children’s organisation of the event. Since no such information was provided, and in the light of the results, no concrete conclusions regarding hierarchical organisation after a single novel experience can be drawn.

2.3 The GER (General Event Representation) Model

A GER is a 'script' representing memory for events that is not specific to a particular experience, but is a kind of generalized knowledge (Nelson and Gruendel 1981). Nelson's (1978, 1981, 1986) GER model was conceived within the general framework of scripts proposed by Schank & Abelson (1977). The script model was originally developed as a
computer model for understanding discourse. Owing to its origins, the script model is a highly specific and rigid structural model of events that may not always corresponds to real life events, or to their representations. A GER is a more flexible model. It makes fewer assumptions about structural characteristics than does a script, and it therefore encompasses generalised representation that do not necessarily meet all of the criteria of a script (Nelson, 1986). Thus a script, as an event schema, is a specific instantiation of a GER.

Nelson's GER model was proposed not only as an explanation for children's memory but as a more general theory of cognitive development. Nelson views generalised event representations as the basic building blocks from which higher level structures are derived. For example, she has suggested a theory of taxonomic development in which the initial taxonomic associations are abstracted from scripts (Nelson, 1985). On this view, the first categories to be established are based on membership in a slot-filler category within a scripted event (e.g. cereal-egg in a breakfast script) rather than on membership in a superordinate category (cereal-hamburger in a food category). Children initially associate slot-fillers in memory because they are substitutable within the same scripts. Superordinate categories emerge when children learn that the same superordinate label can be substituted for items within several different scripts. Superordinate categories are hypothesised to be a more advanced development because they require a higher level of abstraction than slot-fillers. Lucariello and Nelson (1985) found a slot-filler advantage in 3 and 4-year-olds recall of lists consisting of word pairs which belonged either to the same slot-filler category, or to the same superordinate category. However, Blewitt and Toppino (1991) found the same slot-filler advantage for adults as well as for preschool children. The slot-filler advantage, then, may not necessarily imply earlier acquisition (Blewitt & Krackow, 1992), although it does suggest some involvement of GERs in taxonomic organisation.

2.3.1 Script Development

GERs, or scripts, are learned and developed in social-cultural context, over time and through repeated experience with an event. These generalised structures provide a cognitive context with which to interpret different event instantiations. They guide encoding and retrieval of actions within an event, and enable the individual to form plans of actions and make inferences and predictions about possible outcomes. When a new or novel event is encountered and there is no appropriate GER to support its interpretation, a new structure will be formed.
A GER may be constructed in two different ways. First, it may be abstracted across a series of distinct episodic memories, in which case the development of the initial episodic representation will consist of a reduction of specific knowledge into rule-based structures. Second, the initial representation may be general from the onset, in which case script development will consist of the addition of both general (addition of alternative 'paths') and specific (filler slots) detail. The developmental data suggest that after a single encounter with an event a primary generalised structure is already in place (Fivush, 1984; Hudson & Nelson, 1984; Nelson, 1978). This initial structure is already organized as a general set of expectations - specifying actions, actors, props and causal-temporal links between action and states - such that future occurrences of the event can be expected to contain the same basic elements and conform to the same organization (Fivush & Slackman, 1986). Further encounters with the event are incorporated into this primary structure, creating sub-scripts and alternative filler slots that can substitute for one another in different situations (Bauer & Fivush, 1992).

When assessing how scripts develop over time, there is the danger of confounding age with experience because it is difficult to establish whether changes in scripts are due to increasing experience with an event, or due to age related differences in cognitive development. Fivush (1984) attempted to dissociate between these two variables by following the same set of children during their first 3 months in school. During this period, the children were interviewed four times about their daily routine in school. Children were interviewed on the 2nd day of school and then again in the 2nd, 4th and 10th week. To control for interviewing effects, i.e. children recalling their previous interview rather than their actual experience, a control group was interviewed once at the end of the 3 months. Children’s recall of the school-day routine changed in a number of ways. First, the children’s accounts became more elaborated; they mentioned more component activities with increasing experience. Second, temporal organization, which had been evident from the start, became more complex with time. There was an increase in the reporting of conditional actions, e.g. "if it's time for meeting, go sit on the blue line", and in the use of 'before' and 'after', i.e. the children were better able to move back and forth in time when reporting a routine and inserting forgotten activities. Third, the children's accounts demonstrated better hierarchical organisation. They reported more possible actions for different activity categories. Their reports consisted of lists of actions that could be associated with specific activity categories - with list size increasing as a function of experience. Fourth, there was an increase in the level of agreement between
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subjects in the reporting of acts, indicating that the children shared a common representation of the school day routine. The acts most often mentioned tended to be associated with a particular place. The increase in level of agreement about acts seemed to have been related to an improvement in the hierarchical organisation of the event. Finally, scripts appeared to become more abstract and schematized, containing more activities but less detail.

Overall, the data indicated a gradual development from a skeletal generalised representation to a more abstracted and schematized structure. The presence of a temporal organization, and to a certain extent hierarchical organisation (indicated by the frequency with which a number of main activities were mentioned, e.g. come-in, play, work, lunch, go home) in the first interview, suggests that a skeletal structure, conforming to general event characteristics, was formed with the initial exposure. This structure then continued to develop in terms of organisational complexity with repeated exposures.

However, the conclusion that the initial representation was general rather than episodic from the start, is not entirely obvious from these data. The information children were recalling in the first interview was the information they encoded after a single day at school (single episode). This information must have been specific to that first day even if no specific details were mentioned at the interview. That this specific information conformed to general event organisation may suggest that children have some general knowledge about the language of events and they used it to organise their initial event representation, but it does not necessarily indicate that the first representation was generalised (I will make a distinction between knowledge of event grammar and knowledge of event type in Chapter 4). We would not expect adults, let alone children, to have the capacity to encode all event information after a single exposure. On a first encounter with an event, when the majority of information is new, a system of limited capacity would only be able to process part of the information at input. With limitations on how much can be processed, processing priority would be given to large variations in the input, i.e. central components of the event. Consequently, main acts, such as play, are more likely to be remembered than finer details, e.g. the particular games played. Thus, the fact that these details were not mentioned by the children in Fivush's (1984) study does not mean that the representation was not specific, but rather that the event presented the children with an informational overload because it was new. Whether subsequent exposures to an event are then fused with this initial representation to create a GER, or whether they each receive a distinct representation which will subsequently be used to abstract a GER, is still unclear. Within the GER model, however, the assumption is that subsequent experiences are
fused with the initial representation. That is, if there is an event representation that corresponds to a current experience, then the current experience will be absorbed by that representation. The question then is what happens to specific episodes? Can a specific episode be recalled or is it lost in the GER forever?

2.3.2 Memory for Specific Events

Hudson (1986) has suggested that specific episodes are organized in memory in terms of their relationship to GERs. Routine episodes that do not deviate significantly from an expected sequence of events are absorbed by the GER, with the memory for the specific episode no longer being available. Novel events, which deviate significantly from an expected sequence, will be linked in memory to GERs, tagged or indexed by their unusual or distinctive aspects. If an initially novel event is repeated, it will be fused with the initial representation, which was originally tagged in memory as a specific episode, and will be incorporated into the GER as an alternative action or an optional pathway (Hudson, 1986). "This fusion of specific event representations into the GER accounts for the 'schematization' of episodic memory over time and repeated encounters" (Hudson, 1986, p. 99).

Hudson (1990) tested this 'fusion' hypothesis by presenting children with a set of repeated similar events, and examining recall of a specific event instantiation. If, as she claims, specific representations are structurally dependent on generalised representations such that specific episodes are fused with, or linked to a generalised structure, then recall of a specific instantiation would be expected to contain information from related but different events. In support of her 'fusion' hypothesis, Hudson found high level of intrusions (i.e. information from other event instantiation) in the recall accounts of a specific episode. I will return to this study in Chapter 5 which focuses on the subject of intrusions and the relationship between intrusions and structural dependence.

The differential representation of general and specific memories is a key feature in the GER model's explanation of preschool children's recall of events. Children as young as 3 have well-developed event representations for familiar routine events, and they exhibit many characteristics of scripts, including generality, sequentiality and agreement on main and central acts. Yet, they have difficulties with episodic memory. They have a tendency to produce generalised accounts in response to specific questions, e.g. 'what happened when...'. So what is different about young children?
According to Hudson, young children have greater difficulties with episodic memory because they over rely on generalised structures for their recall. Over reliance on generalised representations leads to distortions in episodic recall because deviations from expected sequences are more likely to be corrected to conform to expectations. Hence, younger children will have greater difficulties processing deviant information.

"...younger children tend to rely more heavily on schematic structures in memory than do older children and adults. These types of effects are stronger for younger children, presumably because they use general knowledge structures automatically but are less able to attend to and accommodate deviations." (Hudson, 1986, p. 103).

Since memory for specific episodes is encoded in terms of distinctive aspects deviating from the norm, recall of specific episodes will be poor, and there will be a tendency to provide general information instead of an episodic description when asked about a specific past experience. However, if children are provided with the appropriate cues, and if the cues match the distinctive features of the episodes, then they will be able to retrieve them (Hudson & Fivush, 1991). But then, if children cannot attend to deviations how could they encode the distinctive features of an episode in the first place?

2.4 A Critique of Nelson's GER Model

There are two major problems with the GER model. First, the conclusions are largely based on the assumption that verbal accounts reflect the organisation of the underlying structures. Second, and more important, there is the problem with definitions of terms.

2.4.1 Reliance on verbal accounts

First is the assumption that verbal accounts reflect the organization of the underlying event representation. If a child does not recall details of a specific event when asked "what happened when..." then it is taken to indicate that the details of that specific event are not represented in memory. There are however, alternative interpretations. Young children may not understand the difference between the general question " what happens usually" (present tense) and the specific question "what happened yesterday" (past tense). Harner (1981) has shown that 3- year-old children use the present tense 40% of the time to describe actions that have already occurred. It follows then, that if children do not always use tense correctly they may not understand it correctly either. Thus, using tense as a means of assessing how an event is represented could prove misleading. Using temporal cues such as 'yesterday' may not be
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effective either. I will discuss this further in Chapter 4.

Furthermore, even if the child does understand the difference between tenses s/he may not perceive that the details are important or required and may therefore exclude them from his/her account of the event. Cuing children about more specific aspects of an event, by asking more detailed questions than those used in Nelson's paradigm, has been found to produce more successful results (Hudson & Fivush, 1991). The children in the Hudson and Fivush study could recall specific information about a novel event - a trip to the archaeology museum - a year later with the best retrieval cue being 'museum of archaeology'. With the appropriate cues, children were able to recall the event 6 years later. Interpreting this within the GER formulation, the cues were seen by the investigators as distinctive 'tags' which enabled the children to distinguish this episode from other occurrences of similar events, i.e. trips to other museums. However, what makes a trip to the archaeology museum distinctive enough to be granted a special representation as a specific memory rather than one to be absorbed by the GER is not clear; and this leads me to the other and more fundamental problem with the GER model, the problem of definitions.

2.4.2 The specific/general distinction

The terms 'novel', 'routine' and 'deviation' are commonly used but not very well defined. A routine event is absorbed by the GER while a novel event, which deviates significantly from an expected sequence, is given a unique representation. 'Novel' and 'routine' are used here as a type of prompt for the particular encoding procedure (tagging or absorbing) that will subsequently follow. Given that the resulting memory structure is a function of event novelty, then a prerequisite for successful retrieval is an appropriate definition of 'novel' and 'routine'. However, 'novel' and 'routine' are defined solely in terms of what is retrieved: if recall was rich in detail then it has been given a unique representation and therefore, it must have been novel; if an event is forgotten or if recall consisted mainly of general details then it was fused with a GER and therefore must have been routine. The circle is now complete: novelty has been defined in terms of retrieval, a concept that itself presupposes a definition of novelty.

In addition, the processes operating during encoding and retrieval are not very clearly specified. Both encoding and retrieval will commence with the process of comparison between an event and the relevant GER. At encoding this will be followed by either fusion or 'tagging'. At retrieval, the comparison process will be followed by a 'running off' of the correct sequence of actions, or in the case of a specific event, access will be gained according to how the event
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is tagged in memory in relation to the GER. The question is how will the specific memory be
tagged in relation to the GER?

If the memory is encoded as a completely separate representation, which it must if the
temporal causal links are to be preserved, then which of its deviant parts will determine the
part of the GER to which it will be linked? Or will the representation be linked as a whole to
as many different parts of the GER as there are deviations? If it is the former, then the memory
could only be accessed via one route. This notion, however, is not supported by existing data.
In the Fivush et al (1991) study, for example, the memory representation of the trip to the
archaeology museum could be accessed using cues other than 'museum of archaeology'. If it
is the latter, then there would be several routes possible to gain access. However, this multiple
representation option defeats the whole point of schematization. It is not economic and it could
potentially lead to multiple GERs of the same event.

If theories are to be evaluated for their power of prediction, then the GER model
would seem to be somewhat limited. The definitions expressed within the model are by and
large post-hoc. The model cannot predict a-priori the type of representation (specific vs
general) of a given event. Within its restricted specification of process, it also cannot decide
a-priori the type of encoding and retrieval processes that may operate on these
representations. As a result, the methodology used to retrieve this information, which must
be decided a-priori, could fail to reveal what is really going on, especially with young
children whose language is still in its early developmental stages. The next section outlines
the schema confirmation/deployment theory which could have potentially addressed some of
these weaknesses in the GER model.

2.5 Schema Confirmation and Schema Deployment

2.5.1 The theory

The Schema confirmation-deployment hypothesis offers a processing explanation to
complement the structural explanation provided by the GER model. It was originally suggested
as a resolution to the question of whether schema-consistent or schema-inconsistent
information is better retained in memory (Goodman & Golding, 1983). Schemas are thought
to guide encoding of event information. The authors proposed two stages to this process: a
schema confirmation stage and a schema deployment stage.

Schema confirmation refers to a process of either finding or building an appropriate
schema. On the initial encounter with an event a broad range of event information is attended to with the aim of finding the best fitting schema with which to interpret the event. Once a schema has been selected, the one that provides the best fit, there follows a period in which one tries to verify its appropriateness by looking for confirming evidence. Here attention will be paid to schema-consistent information. Consequently, recall and recognition of schema-consistent information will be better than that of schema-inconsistent information. If, however, a schema does not exist, and nothing can provide the basis for selectively attending to particular event information, then a new schema must be formed. In the earliest stage of schema formation, attention to details is given in an unbiased manner. Recall and recognition during this stage will, therefore, be at an equal level for both schema-consistent and schema-inconsistent information.

Once a schema had been confirmed, a period of schema deployment is entered. During this stage, attention is no longer needed for overall comprehension of the situation, since the confirmed schema now provides the basis for interpretation. Instead, attention is redirected to new and unusual information - to schema-inconsistent information. For example, when subjects are presented with a picture of a farm scene that includes an octopus, their first fixation is on the octopus (Loftus & Mackworth, 1978). Farrar and Goodman (1990) have suggested this to indicate an instantaneous confirmation of a schema (e.g. the farm scene), followed by an immediate onset of a schema-deployment stage that is too quick to enable detection of schema-confirmation. As processing resources during schema deployment are focused on discrepant information, encoding of such information is now given a priority. This information is then encoded as a separate memory and linked to the schema as a distinct memory:

"Attention is thus freed for the processing of inconsistent information, for the establishment of a distinct memory for that information, and for linking discrepant information to the schema". (Farrar & Goodman, 1990 p. 37).

A schema deployment stage cannot occur before a schema is confirmed, and it may not occur at all for developing schemes.

By this account, young children are not able to recall specific events because they stay longer in the schema confirmation stage. Due to more limited processing skills and a reduced knowledge base, younger children will take longer to develop a schema and will, therefore, remain in a schema confirmation stage longer than older children. Their recall will, accordingly, be dominated by schema-consistent information at the expense of episodic detail.
2.5.2 Evidence

Farrar and Goodman turn to the areas of problem solving, social cognition, and cognitive development for supporting evidence. They suggest Johnson-Laird to have uncovered confirmation biases in problem solving tasks, particularly when the stimuli were less familiar. From the social cognition field, the authors take as an example White and Carlson’s (1983) study on the use of schemas in attention and impression formation in social interactions. Subjects in this study were presented with information about a target actor and then viewed a videotape in which the actor was engaged in a conversation with another unprimed actor. The primed actor first behaved in a schema neutral manner, and then in schema inconsistent manner. It was found that subjects first attended to the primed actor (schema confirmation), then to the other actor. They only returned to observe the primed actor when he started behaving in an inconsistent manner (schema deployment). From the developmental literature the authors take as an example studies on habituation in infants. In such studies infants are said to develop a schema of the stimuli during familiarization trials. The novel stimulus that follows violates this schema and is therefore attended to. The finding that infants prefer a familiar stimulus when the stimulus is complex (Hunter, Ross & Ames, 1982), is explained in terms of the infant having to remain longer in a schema confirmation stage.

All these studies, however, only provide indirect support for the theory. None was designed specifically to test the schema confirmation/deployment hypothesis. The only study which was specifically designed to test Farrar and Goodman’s theory, and in particular the hypothesis that younger children have difficulties with specific episodes because they remain longer in a schema confirmation, was inconclusive. The study in question (Farrar & Goodman, 1990) looked at developmental differences between 4-year-olds and 7-year-olds in terms of their organisation of events. It examined the children’s recall of features of a repeated event (which will be referred to as the script visit), and of features of a specific event (the episodic visit) in which deviations from the repeated episode were introduced. The events were introduced on four different visits over a two-week period. The episodic visit was either first or last in the series. Memory for the events was assessed a week later under free and contextual recall situations. Memory for the episodic visit and the script visit was tested on the same day. Overall, the study found the same level of recall for both script and episodic visits with the two groups. However, the authors also found that 4-year-olds had more difficulty distinguishing between the episodic and script visits; they were more likely to confuse event
features between the standard and deviation visits. The confusion, according to the authors, indicated that young children were still in a schema confirmation phase. The differences between the groups were taken as support for the schema confirmation/deployment hypothesis. However, A number of alternative interpretations may be just as viable.

First, the complexity of the event was such that it is quite possible that the 7-year-olds, as well as the 4-year-olds, were in fact still in a schema confirmation phase. Therefore, it would be difficult to reject the option that the differences between the two age groups were due to developmental differences in capacity or knowledge, rather than a particular stage of confirmation or deployment.

Second, the interviews for script and episodic visits were given consecutively. Therefore, the observed intrusions of episodic details in the recall of the script visit, and script intrusions in the episodic recall, could be explained as intrusions between the two interviews. In other words, children may have been incorporating information from the first interview into the second interview.

Third, according to the theory, during schema confirmation attention is directed to schema consistent information and not deviations. This would lead to the prediction that children who are still confirming their schema will not attend to deviations, and therefore will not be able to recall deviations at all. In addition, episodic memory would be expected to be relatively poor. Neither of these predictions was supported. I will discuss this study in detail in Chapter 5.

2.6 A Critique of the Schema Confirmation/Deployment Theory

Schema confirmation/deployment theory suffers from the same problem of circularity as the GER model. In their case not only with respect to the definitions of 'similar' and 'deviant', but also in their conceptualisation of the confirmation and deployment processes, and the proposed relationship between these processes and attention. The first difficulty for both theories is establishing a boundary between similar and deviant events which is as distinct as the encoding processes (confirmation/deployment or fusion/tagging) that are characterised in relation to these events. Circularity arises here because a distinction between similar and different cannot be defined independently of the encoding processes which themselves presuppose a definition of this distinction. A second weakness, which is specific to the schema confirmation/deployment hypotheses, is with the characterisation of the confirmation stage. The confirmation stage is used to describe a number of independent entities. It is used to refer
to either a selection or an encoding process, and when associated with the latter, confirmation can direct attention to either differences and similarities or to similarities only. Thus, apart from memory for deviant events, which is reserved for the deployment stage, confirmation essentially accounts for everything else that is relevant to event memory, and it therefore explains nothing.

2.6.1 How Similar is Different?

The schema confirmation/deployment theory, like the GER model, presupposes the operation of different encoding processes on different types of input information to account for different types of recall. Farrar and Goodman express the differences between their encoding processes, confirmation and deployment, in the following abstract:

"...Schema confirmation has different effects on memory performance depending on the level of schema development. If the schema exists, then information consistent with the schema will receive as much if not more processing than information that is inconsistent with it. If, however, the schema is just developing, then event information will be retained more or less equally...During schema deployment, information consistent with the schema requires limited processing because it is expected via the schema. Attention is thus freed for the processing of inconsistent information." (Farrar & Goodman, 1990, p. 37).

Three type of encoding are identified here. During schema development, event information is retained more or less equally; this is followed by the encoding of consistent information, once the schema is developed, and then by the encoding of inconsistent information, once a schema is confirmed. When then, does a schema reach that final stage of development to initiate a deployment process? And how similar to the 'developed' schema must subsequent events be to justify a deployment stage, and how different to maintain, or reinstate, the system in a confirmation stage?

The problem here is identical to the one I have discussed earlier in relation to the GER. The different encoding operations are specified in terms of the relationship between the generalised structure and the input information (although, unlike the GER, this relationship can now vary with schema development as well as the 'routiness' of the event). However, since there are no independent means by which to establish the level of schematization of a schema - or more pertinent to this argument - the degree of deviation from a schema, there is no way of identifying in advance the particular encoding process that will operate on the input. It is only a retrospective analysis of recall that could identify the encoding process that was
operating at the time: If event consistent information was recalled, then the schema was still being confirmed; if inconsistent information was recalled, then schema deployment process was active; and if a mixture of the two was observed, then the schema was being developed.

This circularity is unavoidable and it all starts with the assumption of distinct encoding processes for similar and different events. By making this assumption, both theories are committed to a boundary that divides a continuous scale - the degree of correlation between an event and the schema that supports its interpretation - into two distinct categories of similar and different. Such that on one side of the boundary, the degree of correlation between an event and a schema is sufficiently low to trigger one type of processing, and on the other the correlation is sufficiently high to trigger another, different, type of processing.

First, even if it were possible to define a boundary between similar and different, there is still a problem of assessing the relationship between an event and a schema because this relationship is not fixed. An event can be similar to a schema in parts and different in others. It is only in retrospect, therefore, that an event as a whole can be identified as either similar or different, but by then the information would already have been encoded\(^1\). On the other hand, making local decisions about the degree of correlation between an event and a schema, and allowing the encoding processes to alternate, could potentially result in the loss of temporal and hierarchical information, since the links between those parts which are similar (and are absorbed) and those parts which are different (and are tagged) would be lost.

Second, given that processing is dependent on the degree of correlation between an input and a schema, the first problem facing the memory system is one of identification. Somewhere along the line the input must be identified as being either similar or different. The most likely way for this to be achieved is through a process of comparison between the incoming information and an existing long-term representation. If the input information is different from the GER, then attention is directed to schema-consistent information, and if the input is similar to the schema then attention is directed to differences. However, in order to confirm similarities one must be able to notice the differences, and vice-versa. Thus, when an input item is compared to a schema item to reach a similarity or a difference judgment, for any judgement of similarity there would have to be a potential judgement of difference, and for this

\(^1\) In the schema confirmation/deployment theory, a relationship between an event and a schema can be identified as different either because the event deviates from an established schema, or because the schema has not developed yet, in which case a routine event will be considered deviant too.
reason, confirmation and deployment stages must be essentially the same. I would suggest the confirmation stage is generally redundant because, as defined, it is used to refer to too many different entities and, therefore, it provides no reference at all.

### 2.6.3 Characterization of the Confirmation Stage

Confirmation refers to the stage of either finding or building a schema. However, finding and building a schema are two independent processes, one involved in selection (or the activation of a schema) and the other with manipulation of information, i.e. encoding. Including them in the same definition only complicates matters. Focusing on confirmation as an encoding stage, however, presents a second problem; specifically, that of distinguishing between the stage of confirmation when a schema is developing and attention is directed equally at similarities and differences, and the stage at which a schema exists and attention is directed at similarities only.

If we assume that it is only during the initial experience, when there is no schema, that attention is equally directed at all event information, then on subsequent experiences when attention is directed only at similarities, the potential for schema development is limited. The schema could not develop beyond the strengthening of existing elements, and then only those that correspond to the current experience. This may mean that similarities will be better remembered, but it will also mean that less is remembered each time an event is experienced since the number of items shared by three events will be smaller than the number of items shared by two. On the other hand, if we assume that attention is equally divided as long as a schema is developing, then what would be the difference in terms of the state of the schema between the confirmation stage that follows (i.e. when attention is directed only at similarities) and deployment? And if there is no difference in terms of the schema then what would determine whether similarities or differences are attended to? Or is it the case that during the period in which a schema exists but it is not fully developed, attention is directed at similarities? However, before a schema has been fully developed, some schema-consistent information may be just as inconsistent to the naïve experiencer as schema-inconsistent information; for example, a horse in a farm will be as inconsistent as an octopus to a child who doesn't know much about farms. Thus, it will not be possible to decide about consistency before a schema has developed sufficiently, by which point a deployment stage should be in force.
If the stage at which attention is directed at similarities cannot be defined, there seems no point in postulating a confirmation process at all since attention during the other two encoding stages is directed at differences anyway.

Differences, I believe, are generally more interesting and more informative than similarities. There must always be a structure with which to interpret a current experience. This structure may be more or less correlated with an experience but, whatever the degree of correlation, the similarities will always be provided by the structure and it is the differences that the system should be concerned with. This would be true not only as Farrar and Goodman suggest during the deployment stage, but also during the confirmation stage. The only difference between deployment and confirmation is that in the former the number of differences between the structure and the event is reduced to deviations from the routine. In other words, attention is always directed at differences. In the extreme case, the majority of information is different from the particular structure that is used for interpretation, but as the event becomes more familiar, the number of differences gradually decreases until it is reduced only to deviations from the routine. At this point the natural attentional bias towards differences becomes evident, rather than as Farrar and Goodman suggest changes from similarities to differences.

2.7 An Alternative

My assumption is that encoding processes are fixed and independent from schema development or event similarity. It is only necessary to postulate two different encoding procedures to account for different types of recall (i.e., specific vs general) if the underlying assumption is of a structural dependence between general and specific representations. If a single generalised structure is to account for both specific and general recall, then the differentiation between the two must occur at the encoding level, when the information is organised in relation to this structure. An alternative option is to assume structural independence and fixed encoding processes. Thus, any event is given a unique representation which may co-exist along-side general/schematic representations of similar events. Recall, in this case, will depend on the type of cues that are being used to access the information, rather than on the particular encoding process that was triggered at the time. Circularity is avoided here because cue type is not defined in terms of recall but in terms of the event itself. In the case of the general-specific distinction therefore, it is possible to make relatively solid
predictions about type of recall as a function of cue type. In the next chapter I will present an alternative memory model based on Morton et al's (1985) Headed Record framework which provides a clear and detailed description of encoding and retrieval processes and the representations on which these processes operate. The developmental perspective and a discussion of the general/specific distinction will then be outlined in Chapter 4.
3. THE HEADED RECORDS FRAMEWORK

3.1 An Overview

This chapter outlines Morton's (1985, 1986) Headed Records (HR) framework. First, a distinction is made between a framework, a theory and a model. This is followed by a synopsis of the framework's kernel assumptions and derived concepts. The set of kernel assumptions and derived concepts in conjunction with a set of additional assumptions are then used to define a rudimentary HR model of memory. Part of this model will be further developed in the course of the thesis to reach the necessary level of specification for implementation.

3.2 The Distinction Between a Framework, a Theory and A Model

A framework provides a set of postulates by which specific theories or models can be derived. The most important feature of a framework is its completeness. When a framework's basic set of postulates is well specified, it will have the resources to explain any pattern of data within its domain. The validity of any given framework, therefore, cannot be refuted. It may be judged in terms of scope and ease of explanation and abandoned if proves limited or cumbersome, but it cannot be tested. A specific theory or model expressed within a framework, on the other hand, can be empirically tested and subsequently falsified. If in the light of the empirical evidence it is found necessary to revise the theory or model, the revised version will still be related to the original by virtue of being expressed within the same framework (Morton & Bekerian, 1986). Thus, the original logogen model (Morton, 1969) is related to the revised model (Morton, 1979) by virtue of being expressed within the same modular information-processing framework.

Morton and Bekerian (1986) distinguish between kernel assumptions, which define the framework, and additional assumptions, which lead to the formation of specific falsifiable models. Kernel assumptions are the irreducible minimum independent set of postulates, and,
if they are changed, the framework would have different properties. The set of kernel assumptions (KAs) will have a number of implications and consequences which are termed derived concepts. The derived concepts (DCs), like the KAs, are shared by all theories which are expressed within the framework. However, since DCs are derivatives of KAs they do not have the same logical status as the KAs and they cannot be changed independently. Finally, additional assumptions (AA) are more specific assumptions used to define a theory. These assumptions are falsifiable. AAs are often driven by the need to meet particular data and may be revised as a consequence. I will first outline the Headed Records kernel assumptions and derived concepts (from Morton & Bekerian, 1986), and then define the set of additional assumptions used to formulate a rudimentary headed record model of event memory.

3.3 The HR Framework

3.3.1 A Summary of the Framework

The Headed Record (HR) framework views memory as being split-up into headed-record pairs. The record is the unit of storage, and the heading is the key used to access the record. No assumptions are made as to the size of the record. With regard to access, either all of the record is accessed or none. HR pairs are structurally independent from one another. Apparent associations between records are a consequence of cycles of processing. Search of the HR system may be initiated by the perceptual system or by explicit interrogation of memory. Either way, a description will be formed with which to carry out the search. The search will stop when a heading is found that matches the description. The associated record will then be retrieved and made available to other processes. If a heading is not matched, or the retrieved record does not fulfill the task demands, a new description will be formed and the search cycle repeated. Only one Record can be retrieved at a time. In cases where the description matches two or more possible headings then some criterion (e.g. recency) must be applied to resolve the competition.

3.3.2 Kernel Assumptions

KA1: Knowledge consists of headed-record (HR) pairs

Our experience and knowledge is represented in memory as a set of HR pairs. The structure and form of information in the record are completely open. Information may be represented in many different formats, for example, it may be represented as a list, as a network or as a script. There are also no restrictions made on the amount of information contained in a record.
It may, however, be limited by the capacity of the processing systems operating at time of encoding or retrieval. Information in headings is made up of a number of discrete elements, not necessarily related or of the same kind. It may include propositions, visual images or a combination of these. No assumptions are made about the relationship between headings and records. Whether or not they share the same information will be assumed in relation to specific models.

**KA2: HR pairs are independent**

There are no direct links between HR pairs. Apparent associations between HR pairs can only occur at the processing level. They may occur as a result of the encoding processes integrating old information from an existing record into a new record of the current experience. Or, they may occur as a result of the retrieval cycle, such that the information in a retrieved record may be used to form a new description that will then be used to retrieve another record.

**KA3: HRs are unmodifiable**

Once a HR pair is formed, it cannot be updated, replaced or erased. This refers to both heading and records. Any new information which enters the system will be incorporated into a new record. With this assumption, the HR framework departs sharply from most other frameworks. For example, in the schema framework new information is assumed to be integrated with existing abstract knowledge structures unless it is sufficiently different to justify a unique representation (see Chapter 2).

**KA4: Retrieval from memory first involves a match between a description and a single heading**

A description (after Norman and Bobrow, 1979) refers to the information used for a search. Given that search implies selectivity, there must be a description upon which the selection of records is based. Descriptions may be formed from external sources - e.g. explicit questions; or from internal sources such as previously retrieved records, or a list of current goals. The description will be used by the search process to scan the set of headings until a match is found and a record retrieved.

**KA5: A record is made available for further processing only if its heading has been matched**

The fact that a record is made available for further processing does not necessarily mean that the information contained within it will be made explicit, or conscious. For this to happen the record's content must pass an evaluation process. Nevertheless, once a heading is matched, the
information in the accessed record is made available for such evaluation, or it may be used as the basis for the formation of a new description.

**KA6: Search with any description will only lead to the retrieval of one record**

The search process terminates once the matching process is successful. Any possible competition between similar headings must be resolved by some criterion. The specific criterion used, particularly in the case of indistinguishable headings, will be specified as an AA at the theory level.

**KA7: Headings are not retrievable. Information in headings cannot be accessed for recall**

This assumption marks the difference between information in headings and information in records. The heading is the only means by which records can be accessed, but the information used for access cannot be retrieved. Information in records on the other hand can be retrieved but it cannot be used for access. However, nothing prevents the occurrence of the same item of information in both the heading and the record.

**KA8: Perceptual experience is interpreted by reference to our knowledge**

Since knowledge is represented in records, this means that interpretation of current experiences will refer to existing records. This assumption is common to many other theories. However, the HR framework departs from most other approaches in that it makes no assumption about the type of record consulted. In schema theories, for example, it is generalised structures that are used for reference. In the HR framework it may be a record containing a generalised structure, or it may be a record of the most current experience. Which record is used for reference will depend on the particular description that was set up at the time of retrieval.

**KA9: New records can be created from our perceptual experience, from old records or from some combination**

The information in records may be represented in many different formats. It may be relatively unprocessed perceptual information, a record of the perceptual experience itself, an action sequence, or an interpreted experience. Thus, records have a variety of different internal structures which reflect the nature of the information recorded at time of encoding.

**KA10: There exists a task specification**

Task specification may be based on external perceptual data, on questions asked by another person, or on internally generated questions or internal states, e.g. moods. There may be multiple task specifications at any given time but at least one must guide the process of retrieval. Task specifications set experimentally may not always correspond to the actual task specification set internally by the subject.
3.3.3 Derived Concepts

The derived concepts are logical consequences of the kernel assumptions. They have no independent existence, and can only be changed if the kernel assumptions are changed. They too therefore, are not falsifiable.

**DC1: There exists a describer**

A describer is a process or a set of processes responsible for the creation of descriptions. It is assumed in KA4 that retrieval involves a match between a description and a heading. Implicit in that is the assumption that not all the currently available information is, or can be, used in the search process. Thus, a description must be created. The system that selects and extracts the appropriate information from the perceptual data, task specification, or information in records, is referred to as the describer.

**DC2: There exists a header**

A header is a process(es) involved in the creation of headings. It is assumed that headings and records are functionally distinct, one being used for access and the other for storage. Therefore, there should be some degree of structural independence between the information entering a heading and information entering a record. Thus, a separate process for the creation of headings is required. At which stage of processing information designated for headings becomes separate can only be decided in the context of a specific model. Note, that the header and the describer are logically equivalent: since retrieval necessitates a match between a heading and a description (KA4), headings and descriptions must share similar characteristics and are, therefore, likely to be the products of the same system (This will be reiterated in AA2).

**DC3: There exists an interpreter**

Records can be created from experiences which are interpreted by reference to old records (of earlier experiences). The interpreter is the system guiding interpretation and encoding of the new information.

**DC4: There exists an evaluator**

It has been assumed that when a record is retrieved its contents will be compared with the task specification to determine whether it corresponds to the information sought. Similarly, when an old record is used in the interpretation of current experience, some checks must be carried out to assess its continued relevance to the current experience. These functions are carried out by the evaluator.
The describer, the header, the interpreter and the evaluator carry out all HR characteristic activity and are collectively referred to as the characterizer.

DC5: The system effectively exhibits 'restricted content addressing'
In the HR framework it is possible for a piece of information which exists in a record, or several records, to be absent from all the associated headings. Search with such a piece of information will result in no retrieval, and consequently in apparent forgetting (DC9). This is markedly different from network systems which exhibit unrestricted content addressing (Landauer, 1975).

DC6: what is retrieved need not be what one is looking for
A heading may contain an item of information that leads to a successful match and retrieval, but the retrieved record will not necessarily contain the required information. For example, BILL'S ADDRESS, may not be in a record headed by BILL. Instead, it might be in a record headed by NEARBY FRIENDS (Morton & Bekerian, 1986).

DC7: Successive retrieval attempts involve an iteration of the same process
Search with a given description will only lead to the retrieval of one record (KA6). Therefore, when the retrieved record does not satisfy the task specification, either the description must be modified or a new description must be formed and the search process repeated. Additional assumptions must be made to specify when repeated retrieval attempts are terminated and retrieval failure, i.e. forgetting, is accepted.

DC8: Accessibility of a record is partly determined by the discriminability of its heading
Similar experiences may result in the formation of HR pairs that may share similar information in headings and records. In this case, the assumption of one record per retrieval cycle effectively means that similar headings will be competing with each other. The likelihood of a particular item being accessed, therefore, will depend on the distinctiveness of its heading.

DC9: Apparent forgetting will occur as a result of the natural operations of the retrieval processes
One assumption made by the HR model is that once information is represented in a record it cannot be updated, replaced or erased. Forgetting within the HR framework is thus explained in terms of retrieval failure. Forgetting can occur for several reasons. First, there is no heading to match the description. Second, the description may match a heading linked to a record with related but irrelevant information (DC6). Consequently, a record will be retrieved but will fail
to provide the relevant information. Third, since there need not be any relationship between
the content of a heading and the content of a record, a piece of information which exists in a
record may be absent from all the associated headings (DC5). Thus, the information is
represented but is inaccessible (KA7). Fourth, the information available in the task may be
insufficient to allow an adequate description to be formed. Williams and Hollan (1981), for
example, have observed that when information was missing at the retrieval stage, subjects used
a variety of methods to fill in additional information to assist recall, or, in HR terms, to use in
their description formation. For example, when less information was available at retrieval than
was available at encoding, the missing information was supplied by methods such as inferences
and systematic hypothesizing. Fifth, the description may contain information common to other
headings, in which case similar headings (or a more recent heading - AA1) can block access
unless a more discriminative description can be established (DC8).

**DC10: Situational demands influence retrieval**

Task specifications, which guide description formation, are based on both external and internal
data (KA10). Therefore, the situation (external or internal) at the time of memory search can
determine the nature of the description that is set up. Changes in the situation following a
retrieval failure will lead to the formation of a new description which may lead to successful
retrieval.

**DC11: There can be duplication of information**

Since new records are formed on the basis of an interaction between experience and old
records, as well as a result of the processing of one or more records (as in the case of
secondary records - AA7), there is nothing to prohibit duplication of information. There are
also no restrictions made on the number of records that could contain information about the
same event, e.g. the event 'going to Safeways' may be sectioned such that one record would
contain the shopping list, and another the journey.

This concludes the set of postulates defining the HR framework.

### 3.4 The HR Theory

Specifying the framework further, by adding a set of additional assumption (AA) to this
set of postulates, will change the original HR formulation from framework status to theory
status. AAs are data-driven, and thus each of the AAs outlined below is potentially falsifiable.
3.4.1 Additional assumptions

AA1: Search is effectively serial and backwards in time

If two or more records exist, the headings of which match the current description then the most recent record will be retrieved. This is based on the observation that people often recall the last recollection of an event, rather than the event itself (Bekerian & Bowers, 1983). The emphasis here is on the time dimension rather than on the actual operation of the search system. Thus, although the overt characteristics of the search are assumed serial and backwards in time the search process may actually be parallel. For example if one adopts a notion of strength with more recent records being stronger, then a recent heading will effect a match with a description more rapidly and lead to the rapid conclusion of the retrieval cycle. Alternatively, there could be a 'time stamp' included in each heading (Morton, 1971).

That search is serial and backwards in time may be illustrated with the following example. Loftus Miller and Burns (1978) found that when subjects were presented with an event and were then given misleading information during recall of the event, they were more likely to recall the misleading information on subsequent recall trials. The original memory, it was suggested, was changed and was no longer available for recall. However, Bekerian and Bowers (1983), using a similar paradigm, found that the original memory could be recalled if the test material was presented in the same order as in the original presentation. In HR terms, the record of the original memory (in both studies) was blocked by the more recently formed (relevant) record which contained the misleading information. However, by forming a more appropriate description through the use of order information, the original record could be retrieved.

AA2: The describer, the header, the interpreter and the evaluator have overlapping functions

The overlapping functions of the four processes may be conceptualised in the following manner. Before the interpreter can operate, a referent record must be found, which will require the formation of a description from the available information. Therefore the interpreter must be linked to a description. Since retrieval necessitates a match between the heading and the description, the information in the heading and description must be similar in form as well as share a similar index, cf. library index, file by the same procedures as retrieve. Therefore, the header must overlap in function with the describer. The evaluation process must operate continuously to ensure the appropriateness of the current referent record, and it will also have
to be linked to the describer in order to initiate a new description if the situation so requires. The particular configuration, interconnecting HR functions, may vary from one model to another.

AA3: All characterizer activity leads to the creation of new records

Any interpretation and/or retrieval activity will lead to the formation of a new record. Recounting a prior experience may lead to the formation of a new record which will consist of those parts of the prior experience which were recounted, in addition to material that was part of the current experience, e.g. the context in which the event was recounted. Whether or not material which was retrieved but rejected as being unsuitable or inappropriate for the particular occasion will be included is an open question. It is possible that when a sub-script structure is used for interpretation, parts which are not relevant to the current experience may still be included as a result of being part of a whole. The majority of schema theories share this assumption. High false alarm (FA) rates for schema-related information have been construed as evidence supporting the notion that internally generated, schema-based inferences are confused in memory with externally observed information about an event. (e.g. Abelson, 1981; Bower, Black & Turner, 1979; Nakamura & Graesser, 1985; Neisser, 1976; Woll & Graesser, 1982). Schema theories, however, assume that the generalised structure as a whole is activated and therefore memory distortions of this type (i.e. FAs) could potentially occur globally - i.e. anywhere within the schema as a whole. I assume that only information that is part of those sub-structures of the schema that are necessary for interpretation will penetrate into the long-term representation. Of course, this argument hinges on what is defined as a 'whole' or a 'complete' structure, which is a question still unresolved by schema theory. The most important issue regarding AA3, however, is that all characterizer activity results in new records. Thus, it is not assumed that only those experiences evaluated as important or different lead to the creation of new records, but rather that any situation which requires interpretation and/or retrieval, will result in the formation of a new record.

AA4: There are basic recognition and response processes operating outside the HR structure

Processes such as object recognition, word recognition or speech output are assumed to operate outside the HR system. The information reaching the interpreter, therefore, will be processed to some extent. In the specific model outlined below, the information arriving at the interpreter is assumed to have already passed the linguistic mechanisms and is already in a
propositional form. Attention processes are also excluded from the HR system although they are assumed to be linked to and dependent upon it.

**AA5: The conditions on a heading-description match are variable**

Some descriptions may require an exact match between a description and a heading e.g. retrieving the definition of a word. Alternatively, a partial match may suffice. In this case some weighting criteria must be defined which will assign different weights to description items relative to their importance. These criteria will have to be specified in the model.

**AA6: Post retrieval processes are imperfect**

It is assumed that if the content of an accessed record is complex, not all of it will necessarily be retrieved and made available for online processing. Thus, parts of a record may be omitted. How much of it is accessed will depend on the capacity of the on-line buffers.

**AA7: There are primary and secondary records**

Morton (1990) specifies two broad classes of HRs: primary and secondary. Primary HRs result from the normal interpretation of the perceptual world. Primary records may consist of relatively unprocessed perceptual experiences, or records of interpreted perceptual experience. Interpretation is made by reference to existing records, e.g. a record of the most recent relevant experience, or a record of the perceptual processing itself. Secondary HRs result from the retrieval of primary HRs either during reminiscence or if they are used as the basis for narratives.

### 3.5 The HR Model

In this section I will outline a rudimentary HR model, making reference to the specific KAs, DCs and AAs that motivated the inclusion of a module or a link in the overall configuration. I will then extract a number of further assumptions which were made in the context of specifying this model. These model assumptions (MA) should be distinguished from AAs specifying a theory. The latter have more specific theoretical implications than the framework but they too will be sufficiently general (under specified) to be shared by different models. A model is a specific instantiation of a theory, and when the assumptions associated with it are well specified, it should not be possible to reduce them any further. As a specific instantiation of a theory then, a model will be more constrained and easier to falsify. Thus, The relationship between a theory and a model is similar to the relationship between a framework
and a theory. In other words, a model is expressed within a theory which is expressed within a framework. The HR model is illustrated in figure 3.1. in a box and arrow diagram.

**Figure 3.1**
The Headed Records Model

--- > THE RETRIEVAL CYCLE

### 3.5.1 The symbolic representation of elements in the diagram

A rectangular box represents a process module and a rounded rectangle a buffer. There are two types of links between modules in the model. The broken lines and arrows define the retrieval cycle. The direction of the arrows indicates where a particular retrieval cycle function takes place. The continuous lines and arrows indicate the flow of incoming information. The thickness of these lines is an indication of the depth to which the information has been processed ranging: from sensory through propositional to complex structures (e.g. sub-scripts). Information flowing along paths represented by a thin line (from the sensory buffer to attention, or to the head buffer) is relatively unprocessed sensory information. It is, however, assumed that some initial processing, such as object recognition, has already taken place. The
pathways represented by lines of intermediate thickness pass information that has been translated into a propositional format; and thick lines indicate that the information had undergone some additional higher level processing. Note, that these pathways are not necessarily restricted to a particular type of information. It may be that some sensory information or unprocessed propositional information leaks through to the record buffer. There is no reason to assume that this occurs but if there was a leakage, the pathways could, in principle, pass on the information.

3.5.2 An Overview of the Model

The model represents the functions of the characterizer, i.e. the describer, the header, the evaluator and the interpreter (DC1-DC4). An on-line buffer is specified for temporary storage of on-line information. This buffer also acts as a receiver for the referent record. Special buffers are designated for headings and records. These buffers have each their own independent input but they both share the same output to long-term-memory. Specifying independent buffers for headings and records and linking them at output, as opposed to directly (and independently) linking the interpreter and the heading/description formation system to long-term-memory, was motivated by KA1 and KA2. First, a single output to long term memory restricts the units of storage to HR pairs (KA1). Second, it allows for discrete dispatching of HR pairs (KA2) by some criterion which is currently unspecified. Implicit here is the assumption that dispatching of records is a triggered rather than an autonomous (and continuous) process. In addition, the model also incorporates attentional processes and a sensory buffer. Attention and low-level processing are not a prime concern of the HR model (AA4). Nonetheless, there were two reasons for their inclusion: first, to provide an overall picture of the relationship between characterizer's activities and other functions, and second, to impose a distinction between information in headings and information in records.

3.5.3 A Distinction between Information in Headings and Information in Records

One of the framework's kernel assumptions is that information in a heading is not retrievable but is only used to access its related Record (KA7). Records on the other hand can be retrieved but can only be accessed via the heading (DC2). The theoretical distinction between access and retrieval corresponds to the empirical distinction between recognition and recall. Many studies have shown that material which cannot be recalled can be recognised
The Headed Records Framework (e.g. Yekovitch & Thorndike, 1981), i.e. cannot access the record but can directly address a heading. Further, the finding that recognition memory is superior if the test material is presented in the same modality as in the original presentation (e.g. Geiselman & Bjork, 1980), led Morton et al. (1985) to suggest that headings may consist of items in their unprocessed, sensory form. Other information may include environmental features and internal states surrounding the event at time of encoding. Studies showing that recall of word lists is better if there is a match between the mood-state of the subject during learning and at test (Bower, 1981) or a match between the odour present at learning and at test (Schab, 1990; Smith, Standing & de-Man, 1992) lends further support to this suggestion.

The observation of modality effects in recognition but not recall, motivated the first specification of the model: sensory input is automatically fed into the header while the same sensory information is screened by attentional processes before it reaches the on-line buffer. Information in records then, will consists of attended information while some information in headings will be incidental. Incidental sensory information will be absent from the associated record. Such information, therefore, would increase the likelihood of successful recognition but would not affect recall, and since it is sensory, recognition memory would be sensitive to modality effects.

Post-attentional processes, not represented by the model, are assumed to map attended sensory input into a propositional form prior to its arrival at the on-line buffer. The information next becomes subject to interpreter manipulations. The interpreter is assumed to integrate and organise propositional information into higher level structures such as scripts. The output of the interpreter then feeds into a record buffer, and once certain requirements are met and a record is completed, a headed-record is transferred into long-term memory. The interpreter, however, is assumed to have limited resources, and therefore, not all the information reaching the on-line buffer is processed by the interpreter.

The additional link from the on-line buffer to the header-describer system allows propositional information to be relayed to the header, and consequently the heading. The reason for specifying this link which feeds into both the header and the describer will be discussed shortly. The crucial issue for the present discussion is that this link implicates propositional information in the heading. Hence, there may be some duplication of propositional information in headings and records (DC11). Propositional information in headings, however, would be different from that found in the record. Items of information in headings will be unrelated and list like, whereas information in records, which has now passed
an additional processing stage, will be integrated by some rule, e.g. in the case of a list it may be category membership. It is not however the case that all propositional information is shared between records and headings. As not all propositional information is processed by the interpreter, it would be possible to find some propositional information in the heading that is absent from the record. This would account for the observation of superior recognition memory for some minor propositional material as well as for sensory information.

To sum-up, records will consist of attended propositional information most of which has been deeply processed. Information in headings will include some propositional information as well as incidental sensory information. The relationship between information in headings and records, which was left unspecified by KAl, is now determined in the model through the specification of the stages at which encoding of heading information departs from encoding of record information (DC2). The model stipulates the following: unattended sensory information will be in the heading but not in the record; some items of information that were attended to may appear in both headings and records but they will be in a different format; certain propositional information will be shared; and some propositional information will be included in headings but not in records; complex structures will only be found in records.

3.5.4 The interpreter

The interpreter is assumed to integrate and organise propositional information into higher level structures such as scripts. It is also assumed to be involved in constructive processing. Two main sub processes are stipulated as part of the interpreter system - an event parser and an inferencer.

*The parser*

The parser determines the organisation of an event record by providing the hierarchical organization and preserving the temporal structure of the event. Hierarchical organisation, unlike temporal organisation, is not an inherent structure in a real life event. Yet, hierarchical organisation is evident in children's as well as in adult's recall. Such organisation, therefore, must be introduced outside the occurrence of an event, as part of interpretation. The parser was postulated for this purpose. In essence, hierarchical organisation is dependant upon correct identification of event goals and sub-goals, and on the embedding of the more specific elements of an event under nodes of more general information (e.g. filler items--->acts--->sub-goals--->goal).
Temporal organisation specifies the order of occurrence of event items and it is an integral part of an event. Once information enters the system, however, such organisation can be easily disturbed. Urgency, for example, may prioritise processing of certain items over others, consequently upsetting the original order of occurrence. Segmenting an event into component parts to be dispatched as separate records when capacity demands impose such segmentation, would similarly disrupt order of occurrence. The parser preserves such organisation while information is being processed; and when capacity dictates closure of records, it guides segmentation into complete sub-sequences that can then be encoded as separate records with minimal loss of temporal information. I will discuss the operation of the parser more fully in Chapter 4.

**Inference Mechanism**

An inference mechanism will be involved in general reasoning and a variety of problem solving procedures. With respect to event memory inferencing will play a part in interpretation in cases where event information is missing and the parser cannot fill in the missing slots. For example, when only the outcome of a sequence is evident, inferencing could reconstruct the cause. It could resolve ambiguity, or reconstruct event sequences, in such cases where information was not explicit, or when such sequences are misordered and temporally distant (e.g. the cause preceded the effect by more processing cycles than capacity would allow). The inference mechanism and the parser will continuously communicate with one another to resolve any problems that arise during computation of event information.

Generally, the interpreter (or its sub-processors) can deal only with propositional information. It will also have limited resources. Thus, some of the information that reaches the on-line buffer will be lost due to these limitations. Associations between records occur at the interpreter stage when relevant parts of old information (residing in the on-line buffer) are integrated by the interpreter with new information and incorporated into a new record (KA2).

### 3.5.5 Heading/Description Formation system

The header and the describer in this model are joined into a single system. This joint system is referred to as the Heading/Description (H/D) formation system. Two input routes to the H/D system (from sensory buffer and from the on-line buffer) are shared by both the describer and the header processors. Thus the information arriving via these paths is shared by
both processors. This configuration is a logical derivative of KA4 (it was also mentioned in relation to AA2). Since retrieval necessitates a match between a heading and a description (KA4), it must be the case that the information in headings and descriptions share a similar form. Therefore, both processes should have access to the same type of information. We know from the available data that odour has a facilitating effect on recall. For example, when an odour is present during the learning phase of a list of words (propositional information), subsequent recall performance is enhanced if the odour is also present at test (Cann & Ross, 1989; Schab, 1990; Smith, Standing & de-Man, 1992). This suggests two things. First, that smell was used as a description item. Second that it was matched and must therefore have been included as a heading item as well. Odour falls in the category of 'relatively unprocessed' sensory input. It follows then that sensory information is accessible to the describer as well as to the header.

Applying the same reasoning, propositional information should be accessible to the header. If information in records (which has now been specified as propositional) can be used to form new descriptions, then the headings such descriptions can successfully match must equally include propositional information. Therefore the header and the describer should have access to such information. This will also be necessary for the encoding and retrieval of secondary records. Propositional information in headings, however, will be unrelated and list like, whereas information in records will be integrated by some rule. This is based on the assumption that the header (and the describer) only extracts pieces of information from the available array, but it cannot manipulate or modify information in the same way as the interpreter.

Thus, the header and describer share common sensory and propositional pathways. A phenomenological difference between sensory and propositional routes within describer operations can be seen as the difference between spontaneous recall (sensory) and intentional recall (propositional); for example, we cannot generate smell as a cue for intentional recall. In the case of the header, it can be viewed as the difference between implicit learning (sensory) and strategic encoding (propositional).

In addition to the common input routes, the header and describer each have their own unique links. The header links directly to the head buffer. The type of information passed on to the head buffer, and the conditions under which such transfers occur are left open. The describer has two additional connections. First, an output route that feeds into long-term memory. This link does not represent an output in the classical sense of information output,
but rather it represents the scanning function of the describer (KA4). The second is the input from the evaluator. This connection is directly linked to the describer, and is not a pathway for information but rather an all or none link to indicate failure or success of the evaluation process. A negative signal will indicate to the describer that a new description must be formed. A negative signal will result either from failure of the accessed record to satisfy task demands or from the retrieved record becoming irrelevant in the course of the current experience.

Overall, this configuration of the H/D system represents a structural overlap between header and describer, while retaining a necessary functional independence.

3.5.6 The Retrieval cycle

The broken line links in Figure 3.1 define the retrieval cycle. Each link between modules represents a specific function of the retrieval cycle. The describer scans long term memory (DC11). The evaluator scans the on-line buffer to evaluate a record's content. When necessary it also sends signals to the describer to initialise a new description. Finally if all conditions are met, a record is copied from long-term memory to the on-line buffer. There are two reasons for favouring copying into a buffer rather than keeping an accessed structure active in long-term memory. First, copying the accessed record satisfies KA3 and KA9. KA3 states that HR pairs are unmodifiable, and, therefore, no direct manipulations on long-term representations are permitted. However, KA9 states that new records can be created from old records, therefore, information from old records must be made available for the interpretation processes. Copying is a solution that satisfies both assumptions since copies of representations can be manipulated. Second, copying also allows the search process and the interpretation process to be independent. Once the required information had been copied, the long-term-store can be disengaged and thus made available for new searches (when required) without necessitating the loss of the previously retrieved information. If the two processes were dependent then any search process could potentially disrupt the interpretation process (and vice versa), particularly in those cases where interpretation relies on long-term representations (e.g. GER). The link between long-term memory and on-line buffer represents this copying operation.

Thus, the describer forms a description and scans memory for an appropriate heading. If the search fails it forms a new description. If a heading is found that matches, the associated record is made accessible for evaluation (KA5). The evaluation process then checks the
contents of the record. If evaluation is successful, the record is made available for interpreter
manipulations. If the record fails the evaluation process, the evaluator sends a message to the
describer to form a new description. If the describer cannot form a new description retrieval
fails. However, as long as there exists suitable information with which to form new
descriptions the retrieval cycle will continue (DC7).

3.5.7 Summary of MAs

The set of additional AA (AA') associated with the model are listed below:

MA1: Information in headings includes incidental sensory information and some
propositional information. Organisation of information is list like.

MA2: Sensory information enters the header and describer without any header or describer
activity.

MA3: Information in records is propositional and mostly deeply processed.

MA4: Dispatching of records is triggered.

MA5: The characterizer operates on buffers.

MA6: The interpreter is linked to - but is independent of - other characterizer functions.

MA7: The interpreter can only process propositional information.

MA8: The header and describer only extract information, they do not manipulate information.

MA9: Retrieved records are copied into a buffer.

MA10: The describer terminates continual iterations of the retrieval cycle.

These assumptions may be added to and modified during the course of the thesis and in light
of new data. In the next chapter I will discuss development and the possible limitation it may
impose on the memory system as represented by the model.
4.1 An Overview

Chapter 3 introduced an information processing model of human memory based on the headed records (HR) framework. The model represents a fully developed, adult version of the memory system. For completeness, however, the model should be able to account for memory phenomena in young children as well as in adults. We know, from the data presented in Chapter 2, that young children's memory is similar to that of adults' in so much as they can represent and report generalised aspects of events. It is also clear from the data that young children are more restricted in their ability to report specific experiences. The 'young' system then, while similar in many ways to that of the adult, would be expected to vary along certain dimensions. In this chapter I will specify developmental aspects of the model that would account for such variations. My conclusions would be that by the age of 3 the basic functions of the memory system are already in place although they still require some fine tuning. In the latter part of the chapter I will discuss the headed record account of event memory and outline a plan for the experimental work.

4.2 Memory and Central Processing

The HR model incorporates attention and interpretation within the overall structure of the memory system. Interpretation was defined within the HR framework as a necessary component involved in the encoding of information, rather than as a separate prior entity. Attention, on the other hand, was not defined within the framework. It was, nevertheless, incorporated into the model to provide an overview of the relationship between these (attentional) functions and characterizer activity. Attention and interpretation, however, are commonly thought of as central executive functions, rather than as memory functions. So where do we draw the line between memory and central processing? The answer to this may vary between theories and frameworks. In my view, there should be no distinction between memory and central processing. Any theory of memory that aims to specify computational functions will directly implicate some aspects of attention and interpretation in the overall
function of the memory system. Attention, as well as interpretation, will determine the final content and organization of the memory record, and should be specified as part of the encoding procedures. Both processes will rely for optimal functioning on access to, and use of, existing knowledge and must, therefore, continuously interact with the retrieval processes. To realise this interaction, encoding and retrieval procedures will also have to share certain attributes, e.g. the H/D system in the model. At the most basic level then, the final verdict on functional independence between memory and central processing hinges on one's definition of encoding. If encoding is defined as the stage at which the information is transferred into a record buffer and dispatched to LTM (or when it is absorbed into a schema structure) then a distinction between memory and central processing may be established. However, if encoding is defined as the stage at which information is organised, and if such organisation is seen to depend not only on reference to existing structures but also on the operation of problem solving procedures such as inferencing, then memory and central processing cannot be seen as functionally independent. In the latter case, a single, interactive system may provide a more complete characterisation. The HR model (Figure 4.1) reflects such a system.

Figure 4.1

Central processing and the HR model

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2Note however, that this is not so much a theoretical issue as it is a terminological one. Within my conceptual framework the terms memory and central processing may be used interchangeably to refer to those processes that govern organisation and formation of records.
The model in Figure 4.1 may be subject to developmentally associated changes in several ways. First, encoding and retrieval processes may increasingly assume their full adult function from small beginnings. Second, the capacity of buffers involved in on-line processing (e.g. on-line buffer being one such buffer) may increase as a function of development. Third, the acquisition of knowledge, will increase interpretive power. However, since the acquisition of knowledge will affect the performance rather than the competence of the memory system, it will not be discussed further. It is the capacity of the memory (or central-processing) system and the related processes that form the basis of the following analysis.

4.3 Central Processes

Attention, interpretation and retrieval, as already mentioned, are all functions involved in the formation and dispatching of memory records. These processes will determine what information is encoded, how it is integrated into a particular memory structure, and how easily it can subsequently be accessed. I assume these functions are limited by general development, each potentially imposing a specific set of restrictions on memory performance. The following discussion will focus on the specific limitations of the retrieval cycle and the interpretation processes that may restrict children's recall of specific episodes. Although attention is no less important, specifying attentional processes within the model is beyond the scope of this thesis and will not be discussed further.

4.3.1 The Retrieval Cycle

The retrieval cycle is illustrated as an information flow diagram in Figure 4.2. I have already noted that for a record to be retrieved a description must be formed with which to scan memory for an appropriate match. If the search fails, the describer forms a new description (A1). If a heading is found that matches the description, the associated record is evaluated against the task specification. If evaluation is successful, the record is retrieved - otherwise a message is sent to the describer (A2) to form a new description.

\(^3\)Figure 4.2 illustrates the necessary stages for retrieval. Thus, it is a symbolic representation of function rather than structure. A1 in the figure represents a feedback function that is associated with the describer. A2, on the other hand is external to the H-D formation system. It represents the link between evaluator and HD system, and was also represented in the original model.
Of the four sub-components which make up the retrieval cycle (Figure 4.2), all but evaluation are necessary for any retrieval to occur. Specifically, recall will not be possible if memory cannot be searched (a description formed and a heading matched) or if a record cannot be made available for further processing. Thus, forming descriptions, scanning memory for a match, and copying a record must be operational as soon as children demonstrate any recall at all. Since recall of a previously experienced episode is already evident in 11-month-old infants (Bauer and Mandler, 1989, 1992), it can be concluded that these functions are already in place by that age. The efficiency of retrieval, however, may be determined by development, particularly at the description formation stage. It will also depend on the function and competence of the evaluator.

4.3.1.1 The H/D System

The processes involved in the formation of descriptions (and headings) must be based on principles that will have to be learned by the child. These principles may change with development e.g. increase in language-based information. Such changes would determine the type of information extracted for description formation (i.e. sensory vs verbal) and/or the weighting criteria used to judge the relative importance of description items. The latter would be particularly crucial if capacity restricts the number of items per description. In addition to limitation on description formation, chaining of records may also be restricted. I will discuss each of these in turn, using Nelson and Gruendel's (1981) study as an example to illustrate each point. Recall that when young children are asked "what did you have for dinner yesterday?", they tend to provide generalised accounts of what usually happens during dinner instead of what happened during yesterday's dinner (Nelson & Gruendel, 1981). The question affords 'dinner' and 'yesterday' as cues with which to access the required information. Yet the
information which children provide does not address yesterday's dinner, but rather a
generalised account that is more likely to be accessed if 'dinner' alone is used as a cue. I will
refer to this study in my discussion of the developmental restrictions on the H/D system;
however, I do not necessarily suggest that they all constitute an explanation for the children's
performance on this task.

**Language-Based Information in Headings and Descriptions**

With the development of language, a whole new set of language-based elements will
be available for use by the H/D system (Morton, 1990). However, while language development
is still in its early stages, language-based information will be rudimentary and overall less often
represented than sensory-based information. Thus, if children at these earlier stages of
language development rely more heavily on sensory input for heading formation, they would
be more likely to demonstrate competent recall if provided with sensory-based cues for recall.
This effect will be more pronounced with specific events, as general event sequences, by virtue
of being repeated experiences, would have had more opportunity to be verbally labelled by the
adults in the child's environment.

As well as being less represented, some language-based cues may be at a level of
abstraction such that they could not be recognized as valid parameters by the system
responsible for the formation of descriptions, and therefore, would not be included in a
description. Examples of this are words such as 'yesterday' and 'before'. This would result
either in no description being formed and apparent forgetting, or in a non-discriminative
description addressing an inappropriate record. For example, a record containing information
regarding yesterday's dinner will not have 'yesterday' in its heading, since it was not yesterday
at time of encoding. 'Yesterday', therefore, could not be used as a cue for a direct match. It
could, however, still be a part of the task specification and evaluation, and in this capacity it
may be used as a trigger for chaining records and iteration of the retrieval cycle (to be
discussed shortly).

**Weighting Criteria for Description Items**

If capacity limitations restrict the number of items that can be used for descriptions,
then not all available information in the task specification will be utilised, e.g. either 'dinner' or
'yesterday' can be used, not both. Or it may be that not all items in the description need to be
satisfied for a positive H-D match and subsequent positive evaluation, i.e. both 'dinner' and
'yesterday' are used but only one need be satisfied. In either of these situations, some weighting criteria for items in the task specification must be applied in order to create an efficient description and maximise the potential for successful retrieval.

An efficient description should give more weight to cues that reduce the target domain of the search, e.g. 'yesterday' will reduce the target domain of 'dinner'. A developing describer may still be learning the principles by which assignment of weights to individual description items is determined. For example, searching for my friend Avi's address would be more efficient if search is initialised with Avi+address rather than friend+address. The general rule is a rule of entailment: if group A (Avi) is entailed in group B (friends) then A is a smaller group and therefore easier to search. Young children who are still in the earlier stages of linguistic and conceptual development may not have the aptitude to utilise such complex rules. In their case salience would be a more efficient weighting criterion since salient items are more likely to be part of their headings. Thus, even if 'yesterday' is a concept understood by the child, 'dinner' would still be more salient and therefore more likely to be chosen if capacity limitations dictate a choice.

**Chaining Records**

Chaining is the ability to modify, or self-generate descriptions from retrieved records when all the information in the task specification is exhausted. While formation of descriptions, as a basic process, must be operational for rudimentary recall, specific reference to information in records may be a later development. Thus, early in development, only information in the task specification can be used for the creation of descriptions. With development, the describer learns to refer to record information as well. Chaining records is necessary for iteration of the retrieval cycle, and if it is restricted then any recall that necessitates iteration will fail. Accessing information regarding yesterday's dinner by using 'yesterday' as a cue would lead to a successful result, even for an adult, only by going through the retrieval cycle several times, forming a new description each time (see Morton, 1990, for an example). Thus, if children are unable, or less inclined, to chain records they could not use 'yesterday' as a cue even if capacity allowed. I would suggest that this latter explanation is the most probable cause for children's impoverished recall in the Nelson and Grundel (1981) study.
4.3.1.2 The Evaluator

The evaluator, as already mentioned, is not necessary for rudimentary recall. Its role is to monitor the appropriateness of the material (already) recalled, and communicate the results of its evaluation to the describer. However, if evaluation processes are not operational, or if they are limited by development, recall may be inappropriate, impoverished, or absent.

Development may restrict the evaluator in the following ways. First, the evaluator may take on evaluation functions later in development than the basic and necessary functions of the retrieval cycle. Second, the specific feedback function associated with it (see A2 figure 4.2) may not be operational until later in development, even if other evaluation processes are already functional. Third, evaluation criteria may change with age.

No Evaluation

A non-functional evaluator will result in no evaluation of records. This would mean that any successful match will lead to retrieval independent of the appropriateness of the record. Behaviourally this would result in recall laden with irrelevant information, although some relevant information may also be present since the H-D match was successful. For example, the question "What is David's address?" might elicit "the Coliseum" as a response. The last time David (relevant record) was seen was at the Coliseum, thus, the record of this event would be the most recent record of David and therefore highly likely to be accessed. This particular 'David' record would contain location information about the meeting (Coliseum) but not about David's residence. A failed evaluation would allow retrieval of this record and subsequent recall of the record's default location information (example from Morton, 1995, personal communication). The frequency with which this phenomenon occurs may depend on the efficiency of the describer. I assume that the evaluation functions are already engaged by the age of 3, since irrelevant recall is quite rare, but at precisely what age evaluation becomes operational is an open question.

No Feedback

If the link between the evaluator and the H/D system has not yet been established, then failure messages cannot be sent to the describer to indicate whether a new description is required. Thus, if a heading is matched and the record is found to be inappropriate, no additional attempts to retrieve a more appropriate record will be made because the result of
the evaluation process is not fed back through the system. In this case, and unless the accessed record was appropriate, the system will register a recall failure, i.e. "don't remember". Alternatively, the inappropriate record (containing at least some relevant information) will be retrieved by default, but recall, being restricted to relevant information, will be impoverished. The behavioural consequences of this type of failure are different from that of 'no evaluation', in that no evaluation would lead to recall of irrelevant information as well as relevant information, whereas no feedback would result in recall of only a small amount of relevant information.

A retrieval cycle with no feedback will execute only a single retrieval operation. Children's evident need for support for their recall through repeated questioning and provision of cues (Hudson & Fivush, 1986; Wilkinson, 1988) may indicate this particular type of failure (i.e. no feedback), as cued recall could be considered as a substitute for iteration of the retrieval cycle. The need for cues, however, will also depend on the children's ability to evaluate whether or not the information in the record completely - or only partially - satisfies task specification, and on their ability to chain records when the task so requires. For example, if an experience is encoded in a number of different records, it will be necessary to retrieve them in sequence. Note that a lack of iteration of the retrieval cycle could be caused by a breakdown in either the evaluator or the describer functions, whereas an absence of feedback is specific to the evaluator.

**Evaluation Criteria**

It is not yet established how the evaluation process operates. Clearly, it must involve reference to the task specification in order to establish the appropriateness of a record, and, unlike the describer, it will continue to refer to current task specification until the task is resolved. In much the same way as description formation, evaluation will depend on principles learned by the child. Similarly, these principles may change with both language development and conceptual development. As with the describer, capacity limitations and the emphasis placed on certain items within the task specification, at the expense of others, may influence the type of information that is recalled. Note, however, that language and/or conceptual development impose performance, rather than competence, limitation on retrieval. Competence limitations within the retrieval cycle can be associated with feedback, chaining and evaluation. Other restrictions on evaluation and description formation are a consequence of limitations in
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domain-specific functions (e.g. language) and the capacity of the online buffer. Figure 4.3
summarises this analysis. Within the cause category a distinction is drawn between competence
and performance limitations on the retrieval cycle (causes). The effects are distinguished in
terms of consequences for the system and consequences for behaviour.

**Figure 4.3**
_Developmental restrictions on the retrieval cycle_

<table>
<thead>
<tr>
<th><strong>COMPETENCE LIMITATIONS</strong></th>
<th><strong>PERFORMANCE LIMITATIONS</strong></th>
<th><strong>CONSEQUENCES FOR THE SYSTEM</strong></th>
<th><strong>CONSEQUENCES FOR BEHAVIOUR</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>UNINTERPRETABLE/INCOMPETIBLE ITEMS e.g. yesterday</td>
<td>WEIGHTING CRITERIA</td>
<td>NO DESCRIPTION</td>
<td>FORGETTING</td>
</tr>
<tr>
<td>PARTIAL MATCH</td>
<td>DEFICIENT DESCRIPTION</td>
<td>EVALUATION SUCCESSFUL</td>
<td>RECALL RELEVANT BUT INCOMPLETE</td>
</tr>
<tr>
<td>NO ITERATION</td>
<td>EVALUATION UNKNOWN</td>
<td>EVALUATION FAILURE</td>
<td>FORGETTING</td>
</tr>
<tr>
<td>NO DESCRIPTION</td>
<td>RETRIEVAL UNMONITORED</td>
<td>RECALL OFTEN IRRELEVANT</td>
<td></td>
</tr>
</tbody>
</table>

### 4.3.2 The Interpretation Processes

These processes are involved in the interpretation of input information and in the
integration of that information into more complex structures. Two mechanisms are postulated
as the necessary and, at this point, sufficient processes for interpretation: a parser that
understands the language of events, and an inference mechanism that is involved in general
reasoning. The purpose of these is to decode the propositional information and make sense of
the more abstract elements of our experiences. In other words, they decode the relationships
(i.e. spatial, temporal, causal, and intentional) between the different items of information at
input (e.g. objects, people).

The ways in which the interpretation processes may be limited developmentally would
be difficult to establish. They may be all-or-none functions (built into the system and triggered
when the appropriate environmental (internal or external) conditions are met) limited only by
the capacity of the on-line buffer, restricted in terms of the amount of information they can
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process at any given time. Or, they may be limited in terms of their own knowledge-base rules, i.e. the battery of rules associated with each particular process may increase as a function of development and maximise the process's potential within a given capacity. To illustrate the point, I will use the parsing process as an example. One of the parser's roles is to organise event information hierarchically; that is, to embed specific information under nodes of more general information. Using bracketing as a symbolic representation of embedding, with different types of brackets representing different levels of generality, the hierarchical organisation of 'a cinema' script may be expressed in the following way: {'name of film [get a ticket (choose seats (back, front, middle, sides)) (pay, cashier (cash, cheque, card))] [watch the film (usher, seating)] [film narrative...]}]. In this example, a basic (or universal) parsing function would be the insertion of a bracket between event items, whereas a rule would encapsulate some knowledge either about types of brackets (e.g. '[' less general than '{' )", or about positions of brackets (e.g. between main acts, between lists). The question then is, what is meant by the phrase "competence of a process"? Is it the basic, universal, principles (all-or-none function, e.g. insertion of brackets) or the acquisition of a set of rules (e.g. knowledge about type and position of brackets)?

Assume for the moment that competence depends on the acquisition of a set of rules, or algorithms (as opposed to basic principles). With this assumption, I am making a distinction between algorithms which represent knowledge associated with processing procedures (algorithmic knowledge), and representational knowledge which is associated with the actual representations the system computes. In the case of hierarchical organisation, algorithms may be conceptualised as representing knowledge about event grammar, i.e. knowledge about types and positions of brackets; whereas representational knowledge would be the collection of schemas which represent more specific knowledge about event types (e.g. 'choosing seats' in a 'cinema' script is a main act, whereas 'choosing seats' in a 'restaurant' script is an optional act) as well as specific event representations. Algorithms, like representational knowledge, will develop over time and with experience, however unlike representational knowledge, once

4 The type of bracket represents degree of generality: '[]' - goal; '[ ]' - main acts; '{ }' - specific actions.

5 Bold represents a specific instantiation.

6 Note that in relation to the general/specific distinction in event memory, the type of knowledge mentioned above is generalised knowledge about a specific event type, e.g. a film script, not specific knowledge about event type. Specific knowledge in a film script would be knowledge represented by bold typescript, the specific name of the film, etc..
they reach a rule status they become part of the 'know-how' of the process. Now, however, the question of (the interpreter's) competence cannot be resolved. Is it really possible to conceive of an ultimate state (when the necessary set of algorithms has been acquired) of competence of a central, domain-general process? Or should parsing and inferencing be viewed as domain-specific abilities? But then, if any process that depends on the acquisition of rules for competent function must be domain-specific, then central processing is reduced to nothing more than a network of input and output routes to and from the on-line buffer(s). The competence of central processing is then reduced to the capacity of on-line buffers and to the establishment of their links (and possibly to the development of the inhibitory mechanism of the attentional system that control the content of such buffers), in other words, to the maturation of the hardware.

I will not attempt to resolve this theoretical issue. Within my framework, both parsing and inferencing are involved in high-level processing, and at the same time they are both thought to depend on the acquisition of a set of rules for efficient performance. As to the original question of whether central processes are limited by general capacity or by their own knowledge-base, I would argue for both. However, empirically, the boundaries between processing efficiency and capacity have been proving difficult to establish.

The question of 'what develops?' capacity (processing space) or speed of processing (the latter being indicative of the efficiency with which 'central' processes are utilised) has been a matter of some dispute. Some argue for a gradual increase in capacity (Alp, 1994; Halford and Wilson, 1980; Kail, 1991, 1995; Pascual-Leone, 1970; Pascual-Leone & Baillargeon, 1994), and others for the development of more sophisticated central processes and strategies within a system of developmentally fixed capacity (Case, 1985, 1995; Chi, 1978, 1982). The point of interest is that in the latter approach it is knowledge, but never capacity, that is assumed to determine speed of processing. For Case (1985), it is operational speed that increases with age. As children's language skills become more efficient there is a reduction in the demands on the limited attentional system, thus allowing them to perform operations such as rehearsal more efficiently. And yet rehearsal training has not been shown to reduce or eliminate age differences in memory span (Kail, 1984). Applying his working memory model to Case's data, and to Hitch and Halliday's (1983) findings on word-length effect on children, Baddeley (1986) has focused more specifically on an increase in articulation rate as the causal determinant of memory span. However, given that most of the evidence concerning the
relationship between articulation rate and span (Hitch, Halliday & Lettler, 1989; Hulme &
Muir, 1985; Nicolson, 1981) is correlational, a causal link cannot justifiably be established.

Kyllonen and Christal's (1990) findings of high correlations between working memory
capacity and reasoning ability and between capacity and processing speed, reinforce the
argument. It is difficult to tease apart the causal factor limiting performance, i.e. capacity or
speed, when both vary together. Even if a task is modified so as to reduce capacity demands
and performance is subsequently shown to improve, the question still remains: was the
improvement due to a reduction in the amount of information the buffers were required to hold
(all information could enter the limited space), or was it due to a reduction in the amount of
information that the system was required to process? For all intents and purposes it does not
really matter whether information never enters the buffers or whether it is overwritten before
it is processed. The main point is that there are developmental changes in the amount of
information that the system can handle at any given time. It would appear that I have turned
a full circle - but I have not. In my view, knowledge and speed of processing are not
interchangeable. While processing speed may increase as a function of knowledge, it could
also increase as a function of maturation of the hardware, and it is the latter that may be
synonymous with capacity. However, since it is empirically difficult to partial out capacity from
speed, I will define 'capacity' operationally as the amount of information the system can handle,
and this may vary with both space and speed. Knowledge, on the other hand, is viewed as an
independent limiting factor, although it is still assumed to be correlated with speed. Given my
previous distinction between types of knowledge, however, the relationship between types of
knowledge and speed will have different developmental consequences on the system. With this
in mind, I can now extract two qualitatively independent entities from those three highly
correlated factors, i.e. space, speed, and knowledge. The first is associated with the amount
of information that can be stored, or processed, which is a measure of capacity, and the
second with the actual content of the stored information, i.e. what information is selected for
processing, which is determined by knowledge (universal, algorithmic and representational).
With this final distinction, I can now outline a model of the relationship between competence
capacity and the rest. Figure 4.4 outlines this model.
Figure 4.4 depicts the proposed relationship between competence and types of knowledge, space, and speed. I have distinguished between three types of knowledge in this section: universal knowledge which refers to basic, all-or-none, functions (e.g. insertion of brackets) algorithmic knowledge which is defined as the system's knowledge of processing procedures (e.g. event grammar); and representational knowledge (e.g. schemas). Processing speed will vary with each of these types of knowledge, however, the variability introduced by each would be independent. Universal and algorithmic knowledge determine what I have termed fixed speed of processing. Fixed speed refers to the efficiency of the processors, which, in turn, depends on maturation of basic functions and the development of processing procedures. Fixed processing speed, then, will increase with development as a function of universal and algorithmic knowledge; and fixed processing speed in conjunction with space will determine total capacity. In contrast, representational knowledge will determine relative speed of processing and it will increase as a function of experience. Thus, rehearsal improves memory span but it does not eliminate age differences (Kail, 1984) because rehearsal will contribute to relative speed of processing but not fixed speed, which is fixed by development.

The particular type of information that will be selected for processing will be determined by all three types of knowledge, but it is only universal and algorithmic knowledge that will be responsible for any developmental changes on this (content) dimension. The arrow
between universal+algorithmic knowledge and competence represents this developmental dimension. The answer to the original question, of whether central processes are limited by general capacity (originally referred to as space) or by their own knowledge base, must be that it is limited by both.

Before turning to the analysis of capacity limitation I would like to return for a moment to interpretation, and parsing in particular, and consider the ways in which this process may develop. I will not, however, attempt to identify developmental patterns associated with competent function of the inference mechanism, largely because the inference processes have a more central role in general problem solving, of which event memory is but one specific case.

### 4.3.2.1 The Event Parser

Parsing determines the organisation of an event record by providing the hierarchical organisation, and preserving the temporal structure of the event.

Hierarchical organisation is not an inherent structure in a real life event; it is rather a processing consequence of the parser. The single, most basic (universal) function that would be necessary to postulate for organising continuous information hierarchically is the insertion of a marker (bracket in the previous analogy) whenever there is a change in context (e.g. the termination or initiation of motion). Additional rules, or algorithms, could then define (a) only specific changes in context as requiring markers (i.e. position of brackets - e.g. changes in location); and (b) the level of generality, relative to the rest, of each marked set of items (i.e. type of brackets - e.g. changes within locations more specific than changes between locations).

Although a developmental pattern has not yet been established, it is nevertheless evident from the data that the principles guiding hierarchical organisation change with development. Younger children do not organise events around the same goals as do older children and adults. Nevertheless, there is a high level of intergroup agreement about what constitutes event goals even for the younger age groups (Fivush, 1981; Gruendel, 1980; Rutner, Smith & Padgett, 1990).

The observation of a high level of intergroup agreement suggests the operation of general principles that guide assignment of centrality to event acts; assignment of centrality to some acts, but not others, indicates some knowledge of embedding. On the other hand, the identification of particular event acts as central will vary between ages as a function of relevance and experience with events. For example, relevance may set-up 'eating' in a
restaurant-script of a 3-year-old as a main goal, and as 'going out' in an adult's script, while experience may determine whether or not 'paying' is included as a main act in the same script. Thus, identification of the goal and main acts will change as a function of experience with events, whereas embedding, which is identified as parser's knowledge, will change with development. Some knowledge of embedding must be in place with the first signs of hierarchical organisation (i.e. intergroup agreement about main acts). We know it is already evident in 3-year-olds accounts of events - whether it is present at earlier age is an empirical question.

Temporal organisation specifies order of occurrence of event items. The parser has to preserve such organisation while information is being processed. Temporal information essentially reflects position along a time 'dimension'. Time, however, is not an absolute measure, therefore preserving temporal information in a global sense, i.e. item X occurred at 9.45 and item Y at 10.30, is improbable. The crucial information is local information about the position of a given item relative to its neighbours. Preservation of local temporal information may be afforded through (the parser's) knowledge about the nature of links between event items. Some such knowledge may be acquired through experience with events and their recall, and some may be inbuilt.

That causal links appear in children's recall at an earlier age than simple temporal links (Nelson, 1979) suggests that temporal knowledge begins with causal relations and then subsequently expands with development to encompass simple temporal relations. Furthermore, the advantage in recall of causally related sequences after a single exposure to an event with infants as young as 11-months-old, and the advantage of causality over familiarity (Bauer & Mandler, 1989, 1992) both point to causal-enabling links as possible primitives that exist independent of experience. This is further supported by Leslie's (1987) observation of the perception of cause-effect relationships in 27-week-old infants. He reported that reversal of a causal event produced more recovery of attention following habituation than the reversal of a similar non-causal event. Since the spatiotemporal properties of the events were identical, Leslie attributed recovery of attention to perception of the cause-effect relationship. Although the event in Leslie's study is not of the type that conforms to a script structure, it nonetheless constitute a simple causal structure that could be an example of the most basic building block of a script. My assumption then, is that knowledge about causality, and insertion of markers, constitute the most basic knowledge on which event memory is based, and that it is also a part
of the parser's inbuilt knowledge. Additional knowledge about temporal (or hierarchical) structure is then learned through experience with events and with general conceptual development.

4.4 Capacity

The human memory system has a specific capacity to store temporarily (or process) a limited amount of information (Atkinson & Shiffrin, 1968; Baddeley, 1986, 1992; Baddeley & Hitch, 1977). The evidence suggest that this capacity is more limited in younger children then it is in older children and adults (Alp, 1994; Halford and Wilson, 1980; Pascual-Leone, 1970; Pascual-Leone & Baillargeon, 1994). As younger children's memory systems are more restricted in terms of the amount of information they can temporarily store, their overall processing will be more selective and more segmented in comparison to that of older children and adults.

4.4.1 More Selective Processing

With a reduced retention span, young children would not be able to extract as much information from their environment as would older children and adults. Which information is finally selected for processing will ultimately depend on how the information is attended to. However, since my theoretical model does not attempt to define the particular processes that may govern attention, this issue will not be considered beyond the assertion that loss of input information will be more pronounced in an underdeveloped system. In addition to selective attention, reduced capacity will have two other consequences. First, with restricted capacity less information would be available to be utilised by the describer, and the consequences of this have already been discussed in relation to retrieval. Second, it could potentially lead to loss of propositional information.

In any system of limited capacity, efficiency considerations would dictate removal of old information in favour of new information. Consequently, old information will either be interpreted and consolidated, i.e. incorporated into an HR and transferred to LTM, or overwritten. While overwriting information is a passive consequence of a system overload, interpretation and consolidation are active processes and for this reason they are more expensive computationally. It may be that interpretation and consolidation are a forgone conclusion in the majority of naturally occurring experiences. That is, if attention and
interpretation are governed (to whatever extent), by existing records, and if the same record is used throughout a specific current experience, then any input information that secured selection would also warrant interpretation and consolidation. Nevertheless, some information may still be lost either during interpretation or at the consolidation stage.

First, if information in the online buffer is replaced faster than the parser can attend to it, then some information will be overwritten before it can be interpreted. The speed with which the parser interprets information will depend on its general knowledge about events (i.e. event grammar) and on generalised knowledge of the particular event that is being interpreted (i.e. GER). I should pause here and reiterate the point about speed. The parser's processing speed may vary with both knowledge of event grammar and knowledge of event type. However, the variability introduced by each of these factors is independent. Knowledge of event grammar determines fixed processing speed and depends upon maturation of the parser, whereas knowledge of event type affects relative speed and depends upon experience with an event type. Fixed speed is assumed to increase with development and it is already accounted for within the definition of capacity. Therefore, within an age group with a given capacity, it is relative speed that determines whether propositional information is lost at the interpretation stage, and this in turn depends upon experience with the event that is being interpreted.

As relative speed increases with event knowledge, one would predict that the more familiar the event, the more information would be interpreted (or less information overwritten). Initially, only central event components would be processed, and, with increased familiarity, computational resources would be freed to process more peripheral information e.g. filler items. When an event is finally overlearned (or schematised) then irrelevant information could be focused on. This pattern of learning would be similar for systems of different capacities. However, with systems of larger capacity the learning curve would be steeper.

Second, occasionally it may be the case that some interpreted information no longer fits in with the overall picture, either because the referent record has changed, or because a new piece of information is now providing a better fit. In such cases, whether or not consolidation of this apparently redundant item takes place would largely depend on an overall understanding of that item's meaning and therefore relevance to the overall experience. That is, some items may appear to be locally irrelevant but may turn out to be important in the global analysis. The assumption is that a young system will not have the computational capacity to engage in decisions about global meaning, which is likely to require reorganisation
of interpreted information, and instead of reorganising their structures they will simply replace the old by the new. Children's failure on the Smarties task (which will be discussed in the next section and in Chapter 6) may be underlined by this particular type of loss which I will refer to as destructive update; the former type of information loss will be referred to as passive overwrite.

4.4.2 More segmented processing

As smaller chunks of information are being replaced in the online buffer more rapidly, completion of records would be more pressing. Any experienced event would have to be segmented into a larger number of records or else relevant information may be lost. Partitioning a single event into a large number of records, a larger number than would otherwise be necessary in a fully developed system, will have three main consequences.

First, it would implicate the involvement of more variables in record closure. Previous research has already demonstrated that the most common type of link between acts in 3-4 year old's recall are spatial-temporal links, i.e. location information (Nelson, 1979; Fivush, 1984), and of these invariant links produce better recall than variant links, i.e. an event sequence unfolding in the same location as opposed to more than one location. Thus, locations provide well defined (natural) boundaries within which event actions can be grouped. Changes in location, therefore, afford natural segmentation points for record closure. However, with greater limitations on capacity, other variables may also be implicated. These may include changes of the protagonist, changes in perceived goal or the strength of links between individual items of information. For example, when conditions necessitate the dispatching of a record, the parser would initially maintain only causally-linked sequences as complete structures and introduce segmentation into variently-linked sequences, or even temporally invariant sequences.

Second, each individual HR pair will contain less information. Consequently, accessing an experience in full will necessitate more retrieval attempts. But if younger children are less inclined, or not able, to go through the retrieval cycle more than once, then only the information that is accessed on the first retrieval trial would be produced as a response.

Finally, more HR pairs per event would suggest that information in some or all of the headings may be impoverished and therefore inherently difficult to address. Unless the
It is clear from Figure 4.5 that a more limited capacity has a number of consequences for the system, each potentially leading to attenuated recall, however, it is clear that the relative contribution of capacity and process must be taken into account at every level of analyses. First, capacity may dictate more segmented processing but this will only be a problem if the retrieval cycle is not fully functional. Second, capacity limitations may impose more selective processing, yet it is the parsing process that will determine which information is encoded and how it is segmented. Finally, the formation of deficient descriptions may be imposed by limitations in capacity, but it is the describer's weighting criteria that ultimately decide which particular items are included or need to be satisfied.

**4.5 Children's Failure and Success**

The most important conclusion to emerge from this analysis of developmental limitations on the memory system is that by the age of 3 the basic functions of the memory
system are already in place, although they still require some fine tuning. Two apparent failures were identified. First, greater difficulty in retrieval which is exacerbated by the fragmented nature of processing at this age. Second, greater loss of propositional information due to selectivity. If it is only fine tuning that is lacking then both these failings could be corrected with the appropriate environmental support. The first two experiments to be reported were designed to address each of these failings. One of these also addressed the distinction between specific and general events. I will first discuss the specific/general distinction within the HR framework and then preview these studies.

4.6 Specific vs General Events and the HR model

The HR framework assumes structural independence between GERs (generalised event representations) and specific event representations (ERs). Specific events are actual experiences and are therefore represented in primary records. Since HR pairs are distinct, each repetition of an event will be represented independently of previous, similar, experiences. GERs, on the other hand, represent knowledge about event type and are assumed to be represented in secondary records. GERs are assumed to provide the semantic context necessary for interpretation of events. They are not, however, a substitute encoding process. A GER is triggered on an encounter with an event to aid interpretation, but only those components of the GER necessary for the current interpretation are actively accessed by online processing. These generalised sub-structures are subsequently incorporated into the final unique ER. Why then do young children tend to recall specific events in a generalized form rather than provide specific details? There are two alternative answers. Children either default to those generalised parts of the unique ER when recalling an event, or they access a record in which the GER itself is represented. In both cases this tendency can be attributed to an inappropriate description formation, resulting from either over reliance on verbal cues, or an inadequate definition of the task specification.

First, if younger children are more dependent than older children and adults on sensory input for heading formation, then sensory cues will be more effective than verbal cues in eliciting recall. This effect should be more pronounced with specific rather than general events, as general event sequences would have had more opportunity to be verbally labelled by the adults in the child's environment. Thus, if the child is provided with language-based cues, there will be a higher probability that the description matches a record containing information about
a generalised event, whereas sensory based cues would increase the probability of accessing a specific occurrence. Wilkinson's (1988a) 'a walk in the park' study demonstrated this point.

Wilkinson (1988a) examined the relative importance of sensory and language-based information in preschool children's recall of a routine event. She looked at the effect of context on recall of a specific instantiation of a 'walk in the park' routine. Children were questioned about the walk either in context (while walking in the park), or in the classroom. Recall in context yielded much richer and more specific accounts. The context would have facilitated performance for two reasons. First, children in the context condition could form more discriminative descriptions from sensory information and access individual records associated with particular individual locations. Second, while walking in the park, they could demonstrate what had happened, e.g. playing on the swings, in addition to their verbal reports. This way aspects of the event that were not given a verbal tag, and would otherwise be considered 'forgotten', were given the opportunity to be expressed. The crucial issue here is that the children recalling in context were not 'schema bound' (or, bound by a schematic representation of 'a..' routine), but rather, with the appropriate sensory cues they were able to provide details of a specific episode of an otherwise routine event.

Second, in addition to an over reliance on verbal cues, inappropriate description formation could be a consequence of an inadequate definition of task specification. In Nelson's (1979) study, the question "what happened yesterday during dinner?" affords only 'dinner' and 'yesterday' as cues with which to form a description. However, as already mentioned, the record containing information regarding yesterday's dinner will not have 'yesterday' in its heading, therefore, 'yesterday' cannot be used as a cue unless it is used as a trigger for iteration of the retrieval cycle. Thus, young children, who are assumed to be incapable of iteration, are left with only the 'dinner' cue with which to form a description. Such a description could address any number of records. If a secondary record is addressed then the information retrieved would be general. If a primary record of any one specific occurrence is addressed then the information could be either general (as general information will be included in the record), or specific to that event, even if irrelevant to yesterday's event. Thus, the probability of the child providing any details is relatively small, and the probability of providing details of yesterday's event even smaller, unless more information with which to form a description is provided. Looking at the difference in recall of an event when recall is elicited by general and specific questions is one of the issues addressed by the 'Mickey' experiment.
4.7 The 'Mickey's Balloons' Event - General vs Specific Distinction

The Mickey event focused on two issues: retrieval support (use of specific questions) and structural independence (general vs specific).

One of the two failings associated with the younger age group was defined in section 4.5 as a greater difficulty in retrieval which is exacerbated by the fragmented nature of processing. Owing to their smaller capacity, younger children will segment a given event into a larger number of records. Accessing the event in full will, consequently, require more retrieval operations. However, if young children are also less inclined to chain records, then a single general cue would not elicit a complete account of the event. Instead such a cue would trigger a record, but once the information in the record was exhausted, no further attempts would be made to retrieve additional information.

To illustrate the point, Wilkinson (1988b) looked at the effect of narrative on recall of a novel event. A novel event was staged for the children in a nursery. The event was superimposed on the usual everyday routine. While children were having their tea in the afternoon, a witch entered the classroom looking for her black paper cats. The children were told that they should bring the cats to the witch when they went to the bathroom, say some magic words, and then the cat would tell the witch if they had been good today. After that, they were sent to the staff-room where the experimenter was waiting with an owl, encouraging the children to stroke it and talk to it. Thus, the event can be seen as being made up of three episodes: classroom, bathroom and staff-room. Another group of children was only told the story of the event. All children were interviewed the following day. A week later both groups were told the story of the event, followed by an interview the next day. The interviews consisted of both general questions (free recall) and specific questions (cued recall). The findings of interest were that recall of the event was better than recall of the story in the first interview, and although recall did not improve in either group, the event/story group provided better structured free-recall accounts after the story: there were more items recalled per utterance; and single utterances included information from more than one episode, whereas previously only items from a single episode were included. Thus, it seems that during the event the three different episodes were encoded in separate primary records. Accessing one of these records would only enable recall of the information contained in that record. In order to recall other information new descriptions would have had to be formed. The story, on the other hand, provided a base for a single record. As the story progressed the primary records would have been retrieved to help the child interpret the story. Details from these records could then be
mapped onto the story record and organized by the narrative structure provided by the story. Accessing this record would enable the child to produce a single utterance in a narrative structure.

The ‘Mickey’ event is based on this study, but instead of repeating the event in a narrative form, the event was reenacted a second time. The rationale for this modification is three-fold. First, to explore the question of whether a 2nd presentation of the event would have similar benefits on organisation. Second, it was hypothesised that repetition of an event is more likely to succeed, where the story repetition in Wilkinson's study failed, in increasing recall rates of event information. Third, to examine the structural independence issue. For this purpose a number of event items were replaced in the 2nd presentation, and the rate of between event intrusions was measured. If the HR framework’s assumption of structural independence is correct then even with two near-event-repetitions, single episodes will still be distinguishable. A more in depth discussion of this issue is presented in Chapter 5.

4.8 The Bag Study - Reducing Capacity Demands

The bag study was designed to show that by reducing capacity demands in a task on which young children are known to consistently fail, success rates could be significantly increased. The bag task is a variation on a well known task within the theory of mind domain - the Smarties task. The Smarties task may be an example of loss of propositional information due to selectivity. Typically, children in the Smarties task are presented with a Smarties tube and asked "what do you think is in the tube?" Once they provide the response "Smarties" the true contents of the tube - a pencil- is revealed. The pencil is then returned to the tube, and the children are asked what they had thought was in the tube when they first saw it. Most 3-year-olds state that they had thought a pencil was in the tube, whereas children over 4 answer the question correctly. The same pattern of response is maintained when the question is phrased differently e.g. "What did you say is in the tube?" or when forced choice format is used - children consistently ‘forget’ their original response. In line with the previous analysis when capacity limitations force updating, the 'Smarties' representation is not consolidated because once the true content of the tube is revealed and the tube is then represented as containing a pencil, this original representation is no longer relevant and is therefore destructively updated. Assuming the failure on the original task indicates loss of propositional information due to greater limitations in capacity, then reducing capacity demands should lead to successful performance. This study is reported in Chapter 6.
5. MICKEY'S BALLOONS

5.1 An Overview

In previous chapters I have introduced a number of theoretical perspectives on the relationship between specific and generalised event representations. In this chapter I will outline a new methodology that has been developed to investigate this relationship and evaluate the empirical evidence it has generated. I will then report an experiment that was designed to investigate the relationship and in addition to explore the issue of segmented processing and retrieval support raised in Chapter 4.

5.2 Introduction

Until relatively recently, the most common way of assessing and distinguishing between specific and generalised event representations has been through the analysis of linguistic forms in young children's accounts (Nelson, 1981, 1986). It is now generally agreed that this method of assessment is limited. First, it confuses memory performance with memory competence. Second, the accounts used in such analyses are typically based on events that have already occurred and for which experimenters have no first-hand knowledge nor experimental control. A more promising methodology has recently come to the fore, emerging independently from within both the GER (Hudson, 1990) and the schema-confirmation/deployment camps (Farrar & Goodman, 1990). Within this methodology, children typically participate in a set of repeated similar events, and are subsequently tested for recall of a specific, episodic instantiation. The critical measure is a measure of between-event intrusions (i.e. generalised, repeated information) in the recall account of the specific episode.

Structural dependency (i.e. a single generalised structure to which specific episodes are linked) is hypothesised by the GER model as well as the schema-confirmation/deployment theory. It is no coincidence then, that both theoretical approaches
have independently derived the same methodology with which to investigate the general/specific distinction. The rational is clear: if structural dependency exists between specific and generalised representations such that specific events are merged with - or linked to - a generalised structure, then recall of a specific event instantiation would be predicted to include information from related but different events. If, on the other hand, specific and generalised representations are structurally independent, with each event receiving a unique and separate representation, than no intrusions would be expected in the recall account of a specific episode. Both Hudson (1990) and Farrar and Goodman (1990), using variations on a theme, observed intrusions in young children's recall of specific events, thus lending support to the structural dependency hypothesis. I will first discuss this work and then report a study which challenges the notion of intrusions as being an expression of the underlying structures by demonstrating different levels of intrusions in recall as a function of experimental condition.

5.3 Hudson's (1990) study

Hudson (1986) suggested that specific episodes are organized in memory in terms of their relationship to GERs. Episodes that do not deviate significantly from an expected sequence of events are absorbed by the GER, whereas novel or deviant events are linked in memory to GERs tagged by their unusual or distinctive aspects. Since memory for specific routine episodes is absorbed by the GER, recall of such episodes will be poor with a tendency to provide general information (intrusions) instead of specific, episodic detail. Hudson (1990) tested this hypothesis by comparing children's memory for the same event experienced as either a single episode or as one of a series of similar episodes. The repeated experience of the event was predicted to improve recall, but also to increase the number of intrusions in episodic recall.

Hudson compared two age groups (4.7 and 5.8 year olds) in either a single creative movement workshop (episodic condition) or 4 workshops (repeated condition). All workshops shared a common structure, each including 10 familiar activities such as singing and dancing. However, the particular songs, dances or games were novel and varied from one workshop to the next. Each workshop had the following structure:

Arrive-->Sit in circle-->game-->Song-->Song-->Dance-->dance-->Relaxation-->home
In the repeated condition, children took part in 4 workshops in four consecutive weeks. A week after the last presentation (week 5) the children were interviewed about the 1st workshop (workshop A). Three weeks after that (week 8) they were interviewed about the last workshop (workshop D). Thus, in both cases, recall of a particular episode was tested four weeks later. In the episodic condition, children participated either in workshop A, or in workshop D, and were then interviewed about their experience four weeks later. Within each of the experimental conditions (repeated vs episodic) children were randomly assigned to either a practice group or a control group. In the control group, the children recalled the workshop only once in delayed recall (i.e. four weeks later). In the practice group, the children recalled the workshop twice, once on the same day as its presentation (immediate recall) and again four weeks later. The experimental design is summarised in Table 5.1.

**Table 5.1**
*A summary of Hudson's (1990) experimental design*

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>WEEK</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeated</td>
<td>Practice</td>
<td>Event</td>
<td>Interview</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Event</td>
<td>Interview</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Episodic</td>
<td>Practice</td>
<td>Event</td>
<td>Interview</td>
<td>A/D</td>
<td>A/D</td>
<td>A/D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Event</td>
<td>interview</td>
<td>A/D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A/D</td>
</tr>
</tbody>
</table>

The interview consisted both of general questions (e.g. what happened in the first/last workshop) and specific questions (e.g. what songs did you sing?). Activities referred to at a general level, e.g. "we sang songs" were coded as generalizations. Activities that were mentioned but did not occur in the particular workshop being interrogated were coded as intrusions. The intrusion rate in the episodic condition (using any song as an answer) was used as a base-line against which to compare the rate of intrusions in the repeated condition. Intrusions and generalizations were not included in the analysis of the amount recalled.

Before summarising Hudson's findings, it must be pointed out that her results section does not include a summary of means and standard deviations. Given that four independent
variables (age, condition, practice and workshop) were being manipulated, the lack of descriptive statistics makes it difficult to form a clear picture either of the relationship between a given finding and a particular independent variable, or of the significance of a given independent variable with respect to the overall theoretical model. There were only two unambiguous findings in this study, neither of which was germane to the main experimental predictions.

First, older children recalled more activities than younger children, particularly in response to general questions. This is neither surprising nor novel. Differences in capacity (see Chapter 4), would influence the total amount of information processed and retained as well as the number of memory records created per episode. Thus, if the records of older children contain more information (fewer records per episode) they will be able to provide more information per interrogation; whereas younger children will require additional cues to access additional records, and even then some event information may be absent.

The second unambiguous finding was that children in the practice groups recalled more than children in the control groups. However, when the increase due to repetition was partialled out, the effect of practice was no greater for the repeated condition than for the episodic condition. Since the only difference between practice and control is the additional, immediate interview for the practice group, it can be concluded that interviewing improved recall. We already know that interviewing has an effect on subsequent recall from Ratner et al's (1990) clay-making study (Chapter 2). Ratner et al. found that children's free recall on a 2nd interview session preserved the original structure of the cued recall part of the 1st session. I have suggested this to indicate that the children were recalling their 1st interview session rather than their actual experience. In HR terms, this would mean that during the 2nd interview children were addressing the secondary record of the 1st recall session, rather than the primary records of the original experience. Thus, interviewing would affect recall in that it would lead to the formation of a secondary record which could potentially interfere with the retrieval of the actual experience (primary record). Whether interviewing actually improves recall, would depend on the structure of the interview as this would determine whether the secondary record contains more event information. But I will reserve this discussion for later.

The finding of an interview effect is interesting in its own right but it was not one of Hudson's objectives. The main objectives of Hudson's study were to investigate the development of a GER, and the relationship between specific and scripted events. She
predicted that "recall in the repeated condition would be more complete, better organised, but less accurate than in the episodic condition, because of constructive processing" (Hudson, 1990, p. 180) and she then suggested that the results supported her predictions:

"The focus of this investigation was whether children engage in constructive processing when recalling typical everyday events. The evidence is that they do. In delayed recall, children recalled more about an episode if they had experienced additional similar episodes instead of just one; but with increasing experience, children tended to confuse details of particular episodes" (Hudson, 1990, p. 180).

Children may engage in constructive processing but Hudson's data do not provide evidence to that effect. Delayed recall performance was higher in the repeated condition than the episodic condition but only for workshop A. On the immediate recall test there was no significant difference in the total amount recalled between repeated and episodic conditions for either workshop A or D. If repeated experiences with an event improve recall, then both immediate and delayed recall of workshop D should be better in the repeated condition than in the episodic condition, as a result of the previous three experiences with the event. For the same reason, recall of workshop D should be better than recall of workshop A in the immediate-repeated condition (four experiences for D vs one for A). This, however, was not the case. Children not only recalled more from workshop A than from workshop D on the delayed recall test, but they also recalled the same amount information from workshops A and D in the immediate-repeated condition. It may be the case that workshop D was more complex and therefore more difficult to remember. However, the comparable levels of recall for workshops A and D in the immediate-episodic condition (when there is no effect of repetition) would rule out this possibility. It seems then that repetition of this particular event did not improve recall.

The fact that the delayed recall of workshop A yielded higher scores in the repeated condition than in the episodic condition may be taken as evidence for a recency effect from the last experienced episode. Workshop A in the repeated condition was recalled a week after presentation of the final event, as opposed to 4 weeks difference between 'presentation' and 'interview' for children in the episodic condition. Although children in the repeated condition were asked to recall the first event, the recency of the experience of workshop D may have facilitated recall. The pattern of intrusions could have clarified this point, as more intrusion from D in the recall accounts of A would be expected. The pattern of intrusions, however, was not reported.
As for intrusions, Hudson reported the following results: (I) There were more intrusions in the repeated condition (1.54) than in the episodic condition (0.36 - the baseline measure). (ii) The proportion of intrusions in the recall of both workshop A and D was larger for the repeated condition than for the episodic condition. (iii) Practice decreased the proportion of intrusions reported by older children but not by younger children. However, the differences in the level of intrusions between repeated and episodic conditions were collapsed across age, practice (time-interval), and workshop. It is therefore difficult to pin-down the origins of such differences. For example, was there any difference in the level of intrusions between immediate-repeated A, and delayed-repeated A? A difference would be expected, such that the level of intrusions for immediate-repeated A should be the same as that for baseline (episodic) A, and significantly lower than delayed-repeated A. Similarly, we would expect a workshop effect, i.e. fewer overall intrusions for A than for D, but this was not reported.

In addition, it is not clear how the proportion of intrusions in the recall of workshop A in the repeated condition was greater (finding ii) when the number of intrusions was not (or at least was not reported as being greater). If the number of intrusions for A was the same for both conditions, and if children in the repeated condition remembered more of A than children in the episodic condition (at least in delayed recall) then proportion of intrusions should be less - not more - unless the number of generalisations for workshop A in the repeated condition was smaller than that in the episodic condition (note that the measure of proportions varies with the number of intrusions, generalizations and corrects); but this would go against the GER model's predictions, i.e. more generalisations with repetition. It is also puzzling that practice appeared to decrease the proportion, but not the number, of intrusions reported by older children. This would mean that the number correct was larger for the older group since the authors reported fewer generalisations in older children's recall. We know that practice generally improved recall but nothing about age differences was reported. Finding (iii) then, suggests that a non-significant age-difference for practice may have been present which manifested itself in the analysis of proportion of intrusions. It does not, however, reveal much about the effect of practice on intrusions, and in that respect it is misleading.

Finally, as I have already noted, no information about the pattern of intrusions was provided. The GER model would predict that intrusions would originate from each event

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6 Proportion scores for intrusions were calculated by dividing the number of intrusions by the number of corrects + intrusions + generalizations.
occurrence at chance level. In other words, intrusions in recall of workshop D could originate from workshop A, B or C. Others (e.g. Loftus, 1975; Loftus, Miller & Burns, 1978) would predict interference only from the most recent experience, old information being replaced by new information, or, as I will discuss later in this chapter, from an interview of an event rather than from a near-event-repetition. Each of these predictions is based on different theoretical assumptions. However, with no analysis of the pattern of intrusions these cannot be teased apart. Thus, we know there were intrusions but we do not know why or how.

To summarise, Hudson found that older children remember more information than younger children, and that interviewing improves recall. She did not provide strong evidence to suggest that repetition of an event improves recall, or that similar events are merged into a single structure consequently leading to between-event intrusions in the recall accounts of a specific instantiation.

5.4 Farrar and Goodman's (1990) study

Farrar and Goodman also investigated the effect of event repetition on recall of specific episodes. Their design, however, differed from that of Hudson's in two important ways. First, the repeated event was always the same whereas the episodic event in this study was a deviant event (rather than a specific instantiation of a repeated event), which differed quite significantly from the repeated event in terms of structure as well as specific items. Second, the episodic vs repeated comparison was a within-subject factor as opposed to the between-subject design in Hudson's study. In addition, the difference in age (4 vs 7-year-olds) between the experimental groups was much greater than in the Hudson study.

These methodological differences reflect Farrar and Goodman's emphasis on the role of confirmation and deployment processes in the organisation of event representations. Specifically, that confirmation processes lead to encoding of schema-consistent information, whereas schema deployment focuses on the encoding of schema-inconsistent information. Within this theoretical framework then, the authors were interested in comparing event deviations (inconsistencies) with event regularities (consistencies) rather than specific instantiations (of a specific episode of a repeated event) with event regularities. They were also interested to show that differences between recall of deviant and scripted events are more pronounced in young children who are hypothesised to remain longer in the schema confirmation stage (as they take longer to develop a schema) and are therefore incapable of forming distinct memories for deviant episodes. Since younger children are expected to have
Mickey's Balloons

no distinct memories for deviant and script events, it was predicted that episodic recall within the younger age group in this study would be contaminated with intrusions and that it would be generally poorer for the deviant visit.

Children participated in four workshops over a two-week period. Either the first or the last visit was the episodic visit. Each event consisted of 4 activity tables (e.g. Puppet table), which I will refer to as event tables. Each table including 2 animals and an action these animals had to perform (e.g. a frog, a bunny, jumping over a fence). The 3 script events were identical. In the deviant event there were three changes: one event-table was replaced by a completely new one; on a second event-table, a change was made in the instantiations of the animals and action, while the theme and location of the event-table were maintained (e.g. the Puppet Table involved two new puppets crawling under a bridge); and finally, the sequence of the two remaining tables was changed. On each visit, the experimenter wore an animal costume. Different costumes were used for script and episodic visits. The costumes were later used as retrieval cues.

Children were interviewed a week after the last visit under both free and contextual recall conditions, for both the script and the episodic visits. The order of script and episodic recall was counterbalanced across children within each recall condition. In the free recall condition children were asked a general question - "What happens when you play with -(animal-costume name)?" - about either the script or episodic visit. Additional probes such as "What else?" were also used. The free recall interview took place in a room different to the one in which the event took place. For contextual recall, children were interviewed in the actual room. They were also shown the animal mask associated with the particular visit. The event-tables were present in the room, marking the location of the events, and for each question children were asked to take the experimenter to the event-tables in the correct order, and to describe what happened at each table. If the child did not provide specific information, more specific questions were asked: "What animals do you play with?" and/or "What do you do with the animals?". Once this procedure was completed for one type of visit, it was repeated for the other type of visit. The order of script and episodic recall was counterbalanced across children, but for each child the order in the free recall condition was maintained in the contextual recall.

The authors used proportion scores in their analysis of script and episodic recall. Proportions were calculated as the ratio of the number of correct items recalled to the number of possible event items (20 in total) plus the number of incorrect items (intrusions), i.e.
Correct/(20+incorrect). The authors found that contextual recall was generally better than free recall; that recall of the script visit was better than recall of the episodic visit, and that the 7-year-olds recalled more than the 4-year-olds. Note however, that differences are exaggerated because the measure of proportion correct varies as a function of intrusions. Thus, if younger children include more intrusions in their recall (as the authors found), the differences between their scores and older children's scores will be larger than they would have been had the intrusions not been a part of the equation.

A measure of episodic memory, i.e. memory for deviant information, was derived as the proportion of correct deviations recalled divided by the number of possible correct deviations. Farrar and Goodman found that the 4-year-olds recalled fewer deviations than the 7-year-olds. To assess whether young children were more script-bound, the authors measured script intrusion into episodic recall, and episodic intrusions into script recall. It was found that the younger children reported a similar proportion of (episodic) deviations both in the episodic (14%-correct) and the script recall (16% - incorrect), whereas older children, appropriately included more deviations in the episodic recall (40%) and less in their script recall (9%). The same pattern was found for script intrusions. Younger children included a similar amount of script information in their episodic recall (39%) as they did in their script visit recall (36%). In contrast, 7-year-olds included less script information in their episodic recall (33%) and more in their script recall (61%). The 4-year-olds correctly recalled more deviations when the episodic visit was on day 4 than on day 1. This last finding led the authors to conclude that "event experience facilitates the establishment of episodic memory for repeated events" (p. 52). Or, it could be a simple recency effect.

I will not discuss the conclusions of this study any further because I still find the results difficult to interpret. Farrar and Goodman report their data exclusively in terms of proportions of deviations, and this often obscures the meaning of a particular result to children's overall performance. For example, Why does 16% of the total number of possible deviations in recall of the script visit, i.e. actual deviations/possible deviations, reveal more about recall accuracy than the actual proportion of deviations in the total recall of a given episode? For every given episode, there is a number of correct items recalled and a number of incorrect items recalled; reporting only the proportion of deviations in script recall

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7 For example, assume that young children recalled a total of 12 items, 3 of which were intrusions, and older children recalled 13 items with only one intrusion. According to Farrar and Goodman, there will be a 18% difference between the groups: (12/21=0.57)-(9/23=0.39); whereas without incorporating intrusions into the calculations, there will be a difference of only 15%: (12/20=0.60)-(9/20=0.45).
(intrusions here) and the proportion of deviations in episodic recall (correct here) is confusing and often misleading.

In addition to these esoteric measures and data analysis, a few methodological weaknesses cast further doubts on the validity of this study. First, the questions utilised the present tense verb form e.g. "What happens when...; or, "What animals do you play with?" - in both the episodic and script conditions. Young children typically use the present tense when talking about general events and the past tense when recounting a specific experience (Nelson, 1981, 1984). If linguistic forms are used by young children to differentiate between event types in production, then the same is likely to apply to comprehension. Thus, young children will tend to rely on the type of question to cue them to the type of information they should report. The authors themselves note in the introduction to their study that: "...researchers use different linguistic forms in their questions, such as different verb tenses, to elicit script and autobiographical memories." (p. 41). It is not surprising, then, that the present tense questions used in this study, elicited script information instead of episodic information, particularly in the younger age group. However, it cannot be concluded from this that younger children's representations did not include more deviation information.

A second and a related problem is the consecutive interviews for script and episodic visits. Hudson (1986) and Reese, Haden and Fivush (1993) suggested, on the basis of data from mother-child recall-conversations, that children learn through recall-conversations what categories of information are important to report. If this is correct then children's exposure to the first interview would cue them to report similar information in the second interview. The observed intrusions, therefore, may have been between-interviews intrusions rather than between-event intrusion. I have suggested earlier that interviewing could effect recall by creating a secondary record which could then interfere with the retrieval of the original experience. Loftus (1975, 1978) had gone even further to suggest that recall sessions may alter the original memory representation. She demonstrated that the wording of questions asked immediately after an event can introduce new and misleading information which is then spontaneously incorporated as part of the experience in subsequent recall sessions. Although, more recently she has come to accept the possibility that misinformation may in fact result in the creation of new memories of the experience rather than in the modification of the existing representation (Loftus, 1992; Loftus & Hoffman, 1989).

It is not important for the present discussion whether the underlying mechanism through which interviewing may produce interference is at the behavioural level, at the
representational level or at the processing level. The only important issue here is that consecutive interviewing is a strong candidate explanation for the observed intrusions. Consequently, Farrar and Goodman's conclusion that the level of intrusions indicates that younger children are not distinguishing between episodic and script visits because the corresponding representations are merged during schema-confirmation stage, is not empirically justified.

Between-event intrusions may be a good measure with which to assess the relationship between generalised and specific representations, but their mere presence cannot be used to confirm any given hypothesis. The question to ask is not whether intrusions are present, but rather what are the conditions leading to intrusions and what are those leading to accurate recall. Farrar and Goodman, for example, might have contrasted their 4-year-old group with another group of 4-year-olds who would be exposed to the scripted event on more occasions so as to reach the schema deployment stage and, in this way, improve recall of deviant information. Hudson, on the other hand, could have designed a more distinctive general event, and then analyse the pattern of intrusions, since intrusions from the last event of a set of repeated events tell a different story about structure than intrusions that are randomly sampled from all event instantiations.

Another problem common to both studies concerns the structure of the event. In Hudson's study, the event did not have a strong or complex structure. It lacked an hierarchical structure and the links between event actions were temporally variant. The event in Farrar and Goodman's structure was more complex but only in terms of its hierarchical organisation. The temporal organisation between event tables and within event tables was variant. There were no enabling links between event actions in either event, and there was no specific goal for the child to attain apart from completing the procedure. These factors would generally contribute to an overall impoverished recall in the younger age group.

Thus, there are two things to improve on in order to counter the objections I have raised with respect to Hudson's and Farrar and Goodman's studies. First, create an elaborate event that is meaningful, motivating and therefore memorable. Such an event should have a strong temporal structure, i.e. invariant links between event components (Bauer & Mandler, 1992, 1989; Nelson, 1979; Price & Goodman, 1990), it should provide the child with a goal to attain (Istomina, 1975), and it should allow for a variety of activities in which the child can participate (Feldman & Acredolo, 1979). Second, to identify the conditions leading to interference and generate two alternative situations one which would demonstrate interference
and the other accurate recall. The 'Mickey's Balloons' event was designed to address these matters, and in addition, to explore the issue of segmentation and retrieval support.

5.5 'Mickey's Balloons' an Introduction

5.5.1 The event

The 'Mickey's Balloons' experiment is based on Wilkinson's (1988b) 'witch' study. In Wilkinson's 'witch' event, a witch enters the classroom looking for her lost black paper cats. She then asks the children to bring the cats to the bathroom. When a child arrives in the bathroom the witch says a few magic words so that the paper cat could tell her whether the child had been good that day. The child is then sent to the staff-room to see the experimenter and her owl. 'Mickey's Balloons' is a variation on this theme. I will provide a detailed description of the event in the appropriate section, but briefly, the children were asked to help Mickey Mouse find his lost balloons, help him to send them to Donald-Duck for his party, and then get a surprise. As with Wilkinson's event, the Mickey event unfolded over 3 different locations; in this study, however, there were more activities associated with each location, and there was a goal for the child to attain. The event was structured such that each action sequence was contingent on the successful completion of the sequence that just preceded it, and all leading to the final goal of attaining the surprise. All temporal links between event acts were invariant (enabling links), and all event acts involved the child's participation. The 'Mickey's Balloons' event is depicted in Figure 5.1. in the Method section.

The event was staged for the children during their lunch at the nursery. The morning after the presentation the children were interviewed about the event. They were then divided into two groups: 'interview' and 'event'. A week later the same event was staged, but this time four of the original items were changed to test for interference. The 'interview' group was tested for recall of the first event in the morning, prior to the staging of the second event. Then the second event was enacted (again during lunchtime), and recall of that was tested the next day. Both the 'event' group and the 'interview group were tested for recall of the second event. All interviews included both general (free recall) and specific (cued recall) questions. Comparisons were made between the 1st and 2nd interview in each condition (before the 2nd event for the 'interview' group, and after the 2nd event for the 'event' group); and between the 1st and final interview in each condition (after the 2nd event for both groups). A summary of the design can be found in Table 5.2 in the design section.
5.5.2 Interference

Four event items were changed in the 2nd event to test for interference. The changes were at the filler item level. They did not violate the structure of the event, nor did they involve changes in event actions. This was to ensure that the 2nd event was similar enough to be identified as a repetition to be merged with (GER theory) or compared to (schema confirmation theory) the previous occurrence, rather than be identified as a unique instantiation that warrants a unique representation. Both merging and confirmation of events would be predicted to produce interference in the recall accounts of the 2nd event; in the former case because the events would be confused with one another, and in the later because the confirmation processes would ignore the deviant (target) items, and therefore these (target) items would be supplemented during recall of the 2nd event by the items from the initial experience.

The HR framework, unlike the GER and the schema confirmation models, assumes unique representations for each event irrespective of the degree of similarity between the events. Therefore, it would predict no interference from the 1st event during recall of the 2nd event since the most recent event record would be retrieved. However, in my discussion of Farrar and Goodman's (1990) study, I suggested that consecutive interviewing was the most likely cause for the observed intrusions. Interviewing, like any other characterizer activity, would lead to the creation of new records (AA3 in Chapter 3). These records would not only compete with the records of the actual experience in terms of recency (as they were formed after the event), but also in terms of discriminability in the context of subsequent interviews. If this assumption is correct, then the records created during the additional interview for the 'interview' group (on the morning prior to presentation of the 2nd event) should produce a certain amount of interference since (a) they will be competing with the records of the 2nd event in terms of recency, and (b) the contextual cues in the interview setting will more closely match their headings. Thus intrusions from the 1st event in the recall accounts of the 2nd event would be expected for the 'interview' group, but not for the 'event group.

5.5.3 Segmentation and Retrieval Support

In Chapter 4 I suggested that younger children's greater limitations in capacity will result in more segmented processing. In essence, this means the formation of a larger number of records per event with less information per record. A single retrieval attempt, therefore,
would access only a small portion of event information. Accessing additional event information would then necessitate the retriggering of the retrieval cycle either by using retrieved record information (chaining), or by re-specifying the task, i.e. through the provision of new cues. However, as younger children are restricted in their ability to chain records, they will be able to access an event in its entirety only if they are provided with additional cues. Therefore, free recall (which is confined to general questions of the type 'What happened when...') would be expected to elicit only a small amount of event information, because once information in a record retrieved by a general cue is exhausted, no further attempts would be made to retrieve new material. Cued recall, on the other hand, should enhance performance since the cues provided by the specific questions will compensate for the children's limited chaining ability, and thus allow for a more exhaustive recall. Thus, the amount of information children recall during the free recall phase of the interview is expected to be much smaller than the total amount of information that is in fact available to them for recall.

Children's recall performance may also be enhanced if the degree of segmentation is reduced, leading to the formation of larger records. The degree of segmentation may be reduced by increasing the parser's relative speed of processing through familiarisation with an event. Familiarising children with an event would increase their knowledge of event type (representational knowledge), which in turn would contribute to an increase in the parser's relative speed of processing and to an associated increase in the amount of information (capacity) that could be processed in a single processing cycle. This would have two consequences for recall. First, there would be less loss of information at the interpretation stage, and second, more information would be incorporated into a single record.

The advantage of familiarity with an event is clearly evident in younger children's superior recall of generalised (highly familiar) events in comparison to specific or novel events. The aim of this study is to show that the same would be true of a single repetition of a novel event, independent of the event's novelty or complexity. Thus, children experiencing the event a 2nd time would have some event knowledge (records) to refer to for interpretation, knowledge they did not have during the initial presentations of the event. This additional knowledge should increase the processing efficiency of event information. Consequently, less information will be lost, resulting in greater overall recall after the 2nd event. In addition, more information should be incorporated into a single record, hence the amount of information elicited by a single cue will be potentially greater. The latter can be
measured by the total amount recalled during the free recall phase of the interview. Free recall scores after the 2nd event, therefore, should be greater than free recall scores after the 1st event.

In addition to boosting record size, an increase in processing efficiency may also improve the internal organisation of the record. Wilkinson (1988b) found better structured free recall accounts after presenting children with a story of an event that they had experienced a week earlier. The story seemed to have provided a narrative structure with which to reorganise event information, and although it did not improve either free or total recall scores, an increase in the number of items per utterance in the free recall accounts of the story was evident. If the 2nd presentation of the event has similar benefits on organisation, then more items per utterance should be observed in the recall accounts of the 2nd event.

5.5.4 Summary of predictions
1. Recall of the 2nd event will produce interference in the 'interview' group, but no interference will be observed in the 'event' group.
2. Large differences are expected between the total amount of event information that the children will be able to recall, and the amount of information they will recall during the free recall phase of the interview.
3. Overall, recall of the 2nd event will produce more details than recall of the 1st event.
4. Free recall accounts of the 2nd event will be richer.
5. Free recall accounts of the 2nd event will be better structured, i.e. there will be more items per utterance in the free recall accounts of the 2nd event.

Two comparisons are made to test predictions 2-4. The first is between the 1st and second interview (before the 2nd event for the 'interview' group, and after the 2nd event for the 'event' group) in each condition. The second is between the 1st and final interview (after the 2nd event for both groups) in each condition. Differences in the amount recalled between the groups are expected only in the first comparison since the 'interview' group is compared prior to their 2nd experience with the event. This comparison, therefore, is expected to yield significant interactions between the Group factor and the other factors, indicating a larger increase for the 'event' group than for the 'interview' group on all measures. Difference between the groups should be eliminated in the 2nd comparison. The 'interview' group should now show the same increase as the 'event' group in free and total recall, and the same
improvement in structure. This would either be due to the additional experience with the event, or due to the additional interview. Which of these two is the correct causal interpretation will depend on the pattern of interference, but based on my prediction regarding interference (prediction 1), I would assume the latter. Thus, only main effects in this comparison are predicted.

5.6 Method

5.6.1 Design

A novel event (the visit of Mickey Mouse) was staged for the children during lunch-time at the nursery. An interview (testing recall of the event) was given to each child individually a day later, including both free and cued recall phases. Eleven out of the 22 children were interviewed again one week later. These children will be referred to as the 'interview' group, the remaining children forming the 'event' group. On the same day, and after the second set of interviews was completed, the event was repeated, again during lunch time. On this 2nd presentation, four of the original 27 memory items were changed to test for interference. Other than that, the first and second event presentations were identical. All children were tested for recall of the second event a day later. The experimental design is summarised in Table 5.2.

<table>
<thead>
<tr>
<th>EXPERIENCE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interview Group</td>
<td>Event</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interview</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event Group</td>
<td>Event</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interview</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

The independent variables are:

1. Recall type: 2 levels - free and cued recall. Within subjects.

2. Group: 2 levels - 'event' group and 'interview' group. Between subjects.
3. Interviews: 2 levels - first interview vs second interview. Within subjects.

The first interview is the interview after the 1st event for both groups. The 2nd interview for
the ‘event’ group is the interview after the 2nd event. However, for the ‘interview’ group
there was an additional interview. Thus the 2nd interview for the ‘interview’ group could be
either before or after the 2nd event. In order to test the effect of event repetition, a 2*2*2
mixed design was employed which used the ‘interview’ group’s 2nd interview (before the
2nd event) as the 2nd level in the Interview factor. The other factors were Recall type and
Group. A second 2*2*2 split plot design was carried out to test the effect of the additional
interview on recall. This analysis used the ‘interview’ group’s third interview (after the 2nd
event) as the second level for the Interview factor.

Two additional 2*2 split plot designs were used to analyse the 'mean no. per utterance'
data. These analyses were similar to the above except that the Recall-type factor was not
applicable.

The dependent variables for the mixed designs are:
- DV1 Number of memory items recalled.
- DV2 Mean number of memory items per utterance.

A further independent variable unrelated to the split plot designs is the level of interference
in the recall accounts of the 2nd event (the 2nd interview for the ‘event’ group and the 3rd
interview for the ‘interview’ group).
- DV3 The number of intrusions from the 1st event in the recall accounts of the 2nd event.

5.6.2 Subjects

Twenty two children (11 boys and 11 girls) participated in the experiment. The mean
age was 3:11 years (range 3:5 - 4:4 years). The children were recruited from Coram Fields
nursery in Camden. The children, all middle to lower class, were of mixed ethnic minorities.
Children were allocated to the experimental groups after the first interview. The groups were
matched in terms of the children’s recall performance on the 1st interview.

5.6.3 Apparatus

The materials used for the two events were: a full Mickey Mouse costume; red, blue
and gold balloons; an office clip, which met the requirements of holding the air inside the
balloon and being easy enough for children to operate; a sack with a picture of Donald Duck
glued to it; a gift box with a picture of Donald duck glued to it; a treasure box with a lock and a small key; and Mickey Mouse stickers. The interviews were tape-recorded for later transcription.

5.6.4 The Mickey Event

The event was designed to deviate significantly from the usual routine of the nursery. Therefore, the normal course of events around lunchtime (the time when the event occurred) will be described first.

The usual routine

Just before lunch, the children are gathered in the book-corner and are read a story. This usually takes about ten minutes until the tables are set. Four tables are usually set for lunch, and children sit wherever they wish. When they finish their lunch, each child takes his/her plate to the kitchen and then goes to the bathroom to wash his/her hands and face. They then go into the quiet-room for an hour of quiet games while the classroom is arranged for the afternoon activities.

The event

The event took place immediately after the children had finished their lunch. A collaborator, dressed-up in a Mickey Mouse costume, entered the room looking for his lost red balloons. Prior to lunch, during story-time, a bunch of red balloons was placed in the lobby (otherwise known as 'the peg').

When Mickey entered the room, he told the children that he was very sad because he had lost the red balloons he had wanted to send to his friend Donald Duck. He then asked the children whether they had seen the balloons. In reply, the children pointed to the lobby area shouting 'they are there'. Mickey then told them that he had wanted to send the balloons to Donald for his usual Friday party which he (Mickey) could not attend that week, and asked the children if they would help him do that. He promised a surprise for anyone that would help. The children were told that they should take one red balloon from the bunch (helped by Nasarine - a member of staff), and give it to Mickey in the bathroom when they went to wash their hands and face.

In the bathroom, Mickey asked each child to let the air out of the balloon, by taking off the clip, and then put it in a sack. Mickey then sent each child to the grown-up's toilet to get his/her surprise from the experimenter. In the grown-up's toilet, the children had to unlock
Mickey's Balloons

a treasure box, using a small key, and take one of the many gold balloons that were inside. They were then sent to the quiet-room to play (A detailed script of the event can be found in Appendix 5.1). The temporal and Hierarchical organisation of the event is outlined in Figure 5.1.

**Figure 5.1**

*Temporal and hierarchical organisation of the Mickey event.*

The following items were replaced for the second event:
The red balloons by blue balloons; Nasarine by Miriam; the sack by a gift box; the gold balloons by Mickey Mouse stickers.

**5.6.5 Procedure**

During the two weeks preceding the event, the experimenter had spent an average of two hours a day in the nursery to establish a relationship with the children.

On the day of the event, while the children were playing in the classroom, preparations for the event were being made in the staff-room. The fully blown balloons were transferred from the staff-room to the lobby during story-time when the children were seated in the book-corner. The lobby is not visible to the children at that time. During lunch, the sack and the treasure box (full of surprises) were placed in the bathroom and the grown-up's toilet respectively. The door between the classroom and the rest of the nursery remained shut throughout lunch. In addition, a note asking visitors not to come in was left on the entrance door.

As most of the children came to the end of their lunch, a staff member alerted 'Mickey' in the quiet-room. Mickey waited for about 2 minutes and then knocked on the door and entered the classroom. The event, as described above, was then enacted. The children
went to the bathroom and grown-up's toilet individually. When they had finished in the grown-up's toilet, they were sent to the quiet room where a member of staff was waiting to engage them in the usual quiet-time activity. The event, from beginning to end, lasted for approximately thirty minutes.

Children's recall of the event was tested the following morning. A detailed account of the interview will follow shortly. One week after the event, the second event was staged. In the morning prior to the second event, the 'interview' group was, again, tested for recall of the first event. This yielded the shortest time-interval possible between the second interview of the 'interview' condition and the second interview of the 'event' condition. The second event was then enacted, as before, during lunchtime. Recall of this was tested the following day, with the 'event' group being tested before lunch and the 'interview' group after lunch.

5.6.6 The Interview

Each child was interviewed individually in the quiet-room. The quiet-room was not part of the actual event, and therefore could not provide cues for recall. The first part of the interview tested the children's free recall of the event (Questions 1 and its 3 sub-questions; Question 2). Questions 1 and 2 (below) were termed non-directive questions (ND) as they provided no specific cues for the children. Sub-questions 1a-1c provided general cues about the event (something special, someone special, Mickey). The purpose of these general cues was to focus the children on the event, and therefore, recall initiated by these questions was considered to be free recall.

*Non directive questions*

(1) Can you remember what happened during lunchtime yesterday? Can you tell me all about it?

(1a) Did anything special happen during lunch time yesterday?

(1b) Did anyone special come to visit during lunch?

(1c) Did Mickey Mouse come to visit you during lunch time?

In the following week, the first question in the 2nd interview for the 'interview' group (prior to the 2nd event was:

Can you tell me what happened when Mickey Mouse came to visit?

(2) What else? ....

When the children were unable to provide any more freely recalled information, a series of questions based on more specific aspects of the event was asked. These questions were termed
Directive questions, as they directed the children's attention to particular aspects of the event. The questions followed the same sequence as the event. For example:

**Directive questions**

1. Was Mickey Mouse looking for something?
   1a. What was he looking for?
   1b. Was he looking for something you can play with?
   1c. Was he looking for balloons?
2. What colour were the balloons?
   2a. Were the balloons red/blue?

If the child's reply to a question was either irrelevant, or incorrect, or a simple "don't know", a more detailed question was asked. The sub-questions became progressively more detailed until they explicitly included the answer. If the child still could not remember, the 'answer segment' of the question would be reinforced. The overall structure of the interview (both sequence and detail) was chosen to maximise recall.

The questions were presented in the same order to all children.

### 5.7 Scoring

Twenty seven items for recall were drawn from the event. These are presented in Table 5.3.

<table>
<thead>
<tr>
<th>EVENT ITEMS</th>
<th>EVENT ITEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mickey</td>
<td>14. Take Off (demonstration)</td>
</tr>
<tr>
<td>2. Lost Balloons</td>
<td>15. Let-air-out (burst; break; pss;)</td>
</tr>
<tr>
<td>*3. Red/Blue</td>
<td>*16. Sack(bag)/Present Box</td>
</tr>
<tr>
<td>4. Balloons</td>
<td>17. Put-in</td>
</tr>
<tr>
<td>5. Send (give)</td>
<td>18. Donald's Picture</td>
</tr>
<tr>
<td>7. Party (birthday)</td>
<td>20. Sofi</td>
</tr>
<tr>
<td>8. Peg</td>
<td>21. Treasure Box</td>
</tr>
<tr>
<td>*9. Nasarine/Miram</td>
<td>22. Open Box (turn it; demonstration)</td>
</tr>
<tr>
<td>10. Take Balloon to Mickey</td>
<td>23. Key</td>
</tr>
<tr>
<td>12. Bathroom</td>
<td>25. Gold (grey; white)/Mickey</td>
</tr>
<tr>
<td>13. Clip (handle; string)</td>
<td>26. Quiet Room</td>
</tr>
</tbody>
</table>

(*) Different items for different events, e.g. RED first event / BLUE second event.

The words in brackets represent alternative responses that were accepted as correct.

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9 The remaining questions can be found in Appendix 5.2
It was decided to distinguish between objects, and the actions carried out on these objects (e.g. box; open it) as separate memory items for two reasons: First, some children would demonstrate either the action without saying a word, or only reply "open it". It would be reasonable to assume that failure to give a verbal account of the object is due to a language failure rather than a memory failure. It is difficult to conceptualize a representation of an action without the object on which the action is executed; however, occasionally such memory failure could occur: for example, one could remember opening the drawer and taking something out, and not remember what that something was. Therefore, no assumptions were made concerning language as opposed to memory. In the case where an item was not mentioned it was taken to have been 'forgotten'.

Second, the structure of the interview was such that the questions regarding the actions preceded those regarding the objects. Consequently, the action questions could potentially provide an additional cue for recall. For example, occasionally a child could not remember what s/he had to do, but when asked "did you have to open something" s/he could remember "opening the box". In such cases, scoring actions and objects as separate items enabled me to distinguish between (a) children who needed the additional cue and those who did not, and (b) children who needed the additional cue in the first interview but not in the second or third.

Each child received a free recall, a total recall and an item-per-utterance (I/U) score. Recall was scored according to the correct number of items mentioned. 'YES' answers that were given in response to specific (yes/no) questions during directive recall were not included. On the whole, children repeated the freely recalled items during the directive questioning phase. These items, however, were only counted once for the total recall score. Thus, the free recall scores included information initiated by the non-directive questions; the total recall scores reflected the overall amount of event information remembered. I/U scores were derived by averaging the number of freely recalled items across the number of event-relevant utterances produced during the free recall part of the interview. In addition, the number of errors made during the interview following the second event was recorded for each child.

5.8 Results

5.8.1 Interference

The number of intrusions from the 1st event in the recall accounts of the 2nd event were computed for each child. Four details were changed between events, thus the number
of intrusions could vary within a range of 0-4. Table 5.4 presents the number of intrusions, and the number of correctly recalled (target) items, for each child as a function of Group.

### Table 5.4

*No. of correct and incorrect recall of deviant items for each child as a function of Group.*

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Interview group (3rd interview)</th>
<th>Event group (2nd interview)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>errors</td>
<td>errors</td>
</tr>
<tr>
<td></td>
<td>correct</td>
<td>correct</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>TOTAL</td>
</tr>
<tr>
<td></td>
<td>3 2 2 4 2 1 2 2 3 3 2</td>
<td>1 0 0 1 0 1 0 0 0 0 0 3</td>
</tr>
<tr>
<td></td>
<td>1 1 2 0 0 0 1 2 1 0 1</td>
<td>3 4 1 3 3 4 3 1 4 3 3 2</td>
</tr>
<tr>
<td></td>
<td>4 3 4 4 2 1 3 4 4 3 3 3</td>
<td>4 4 1 4 3 4 3 1 4 3 3 3 5</td>
</tr>
</tbody>
</table>

Comparisons between the 'event' and the 'interview' conditions were carried out using a Mann-Whitney test. The subjects' error scores were entered into the analysis. The analysis revealed a significantly higher level of interference for the interview group ($z = 4.028, p < 0.001$), although there were no differences between the groups in the total number of (target) items recalled; the total was 35 in both conditions.

#### 5.8.2 Overall recall

Table 5.5 shows the mean recall scores for each interview in each experimental condition. The table includes the mean scores for free recall, total recall and I/U.

### Table 5.5

*Mean free recall, total recall and I/U scores for each interview in each condition*

<table>
<thead>
<tr>
<th>Interview Group</th>
<th>1st Interview</th>
<th>2nd Interview</th>
<th>3rd Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Free</td>
<td>Total</td>
<td>I/U</td>
</tr>
<tr>
<td>Intervew Group</td>
<td>mean</td>
<td>3.64</td>
<td>13.18</td>
</tr>
<tr>
<td></td>
<td>sd</td>
<td>5.28</td>
<td>7.39</td>
</tr>
<tr>
<td>Event Group</td>
<td>mean</td>
<td>4.18</td>
<td>13.64</td>
</tr>
<tr>
<td></td>
<td>sd</td>
<td>4.71</td>
<td>7.84</td>
</tr>
</tbody>
</table>

The numbers in bold are the scores obtained in the interview after the 2nd event.
The Effect of Event Repetition on Recall

(comparing the first two interviews in each condition)

In order to test the effect of event repetition on recall, comparisons were made between the first two interviews in each condition. Thus, in this comparison, the two groups differed in terms of number of exposures to the Mickey event - a single exposure for the 'interview' group and two exposures for the 'event' group. The cued and free recall scores were entered into a three-way analysis of variance, with the Recall-type and the Interview factors as within-subjects factors and Group (number of exposures) as a between-subject factor. An additional 2-way ANOVA, incorporating only the Interview and the Group factors, was carried out to analyse the mean I/U scores. Figure 5.2 shows the mean scores of free recall and total recall plotted as a function of Group (number of exposures to the event - 1 vs 2 exposures) and Interview (1st vs 2nd interview). Figure 5.3 shows the plots of the mean I/U scores for each group as a function of Interview.

Three-way analysis for overall recall

Recall-type factor: The total amount of information children recalled was significantly higher than the amount of information they were able to recall during the free recall phase of the interview \( [F(1,20) = 81.01, p < 0.001] \). This difference is clearly apparent in Figure 5.2. Although Figure 5.2 appears to show a greater increase in the total amount recalled for the 'event' group in comparison with the 'interview' group, the interaction between Recall type and Group was not significant \( [F(1,20) < 1] \).
'Interview' factor: Overall, significantly more information was recalled in the 2nd interview than in the 1st \[F(1,20) = 9.73, p < 0.025\]. This effect is apparent in Figure 5.2 which shows an overall increase in the number of items recalled in the 2nd interview in both free and total recall. The non-significant interaction between this factor and the Recall-type factor \[F(1,20) < 1\] indicates that the increase was no greater for one type of recall than it was for the other.

Group: There was no significant main effect for this factor \[F(1,20) < 1\]. This and the non-significant interaction terms indicate no differences between the groups in the amount recalled either as a function of Recall-type or as function of Interview - \[F(1,20) < 1\] in both cases.

**Two-way analysis for the 'Items per utterance' (I/U) data**

A significant main effect was obtained for the Interview factor \[F(1,20) = 7.19, p < 0.02\]. The overall increase in the mean number of items per utterance in the second interview is evident in Figure 5.3 It is also evident from Figure 5.3 that the increase for the 'interview' group was larger. The interaction term, however, failed to reach significance \[F(1,20 = 2.98, p=0.10\]. No significant main effect was found for the Group factor (number of exposures) \[F(1,20) < 1\].

**The Effect of Interviewing on Recall**

**(comparing both groups after the 2nd event)**

An additional set of ANOVAs was carried out in order to test the effect of interviewing on recall. This time, the data from the 'interview' group's third interview were entered into the analyses as the second level for the Interview factor. In these analyses the groups differed in terms of the number of interviews per group - two for the 'event' group and three for the 'interview' group. Again, a three-way ANOVA was used to analyse the free and cued recall scores, and a two-way ANOVA to analyse the I/U scores. Figure 5.4 shows the mean scores of free and total recall plotted as a function of Group (2 vs 3 interviews) and Interview. Figure 5.5 depicts the mean I/U scores plotted as a function of Interview for each group.

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10 An inspection of the standard deviations for the I/U data indicated heterogeneity of variance. The I/U data were therefore rescaled using a logarithmic transformation. The analysis of the transformed data yielded similar results - a significant main effect for Interview \(F(1,20) = 7.08, p < 0.02\), no main effect for Group and a non-significant interaction.
Three-way analysis for overall recall

As before there was a significant main effect for the Recall-type factor \(F(1,20) = 22.48, p < 0.001\), and for the Interview factor \(F(1,20) = 85.72, p < 0.001\). The Group factor and the interaction terms were not significant.

Two-way analysis for the 'Items per utterance' (I/U) data

Both the Interview factor and the interaction between the Group and the Interview factors were significant at the 1% level - \(F(1,20) = 15.63\) for the Interview main effect, and \(F(1,20) = 10.61\) for the interaction. Thus, the increase in the mean numbers of items per utterance was significantly larger for the 'interview' group (3 interviews) then for the 'event' group (2 interviews). This is also evident in figure 5.5. The main effect for Group was not significant \(F(1,20) < 1\).

\[\text{I/U} = \frac{\text{Items}}{\text{Utterance}}\]

\[\text{F-ratios for the rescaled I/U data showed the same pattern: main effect of Interview } F(1,20) = 14.98, p < 0.01; \text{ interaction } F(1,20) = 6.69, p < 0.02.\]
5.9 Discussion

5.9.1 Summary of Results

In general, the results supported the predictions. First, there was a high level of interference in the recall accounts of the 2nd event but only for the 'interview' group; there was no interference for the 'event' group. Second, large differences were obtained between free and total recall in all interviews. The remaining predictions, those regarding free recall, total recall and I/U data, were also supported, however, it appears that the improvements in overall recall were not restricted to event repetition. The results seem to indicated that improvements in recall were also associated with interviewing.

Interference

The observed pattern of interference corresponded to the prediction: recall of the details of the 2nd event showed a high level of interference for the 'interview' group, and a striking degree of accuracy for the 'event' group. As the only difference between the groups (when both were compared after the 2nd event) was the additional interview for the 'interview' condition, it can be concluded that the interference found in this condition was due to the additional interview. Since the lack of interference in the 'event' group suggest that a discrete and 'uncontaminated' representation of the 2nd event was indeed available, it must have been the case that the representation of this additional interview was blocking access to the representation of the 2nd event, and it must have been this (interview) representation (containing information about the 1st event), rather then the representation of the 2nd event, that the children were recalling on their 3rd interview.

There is no alternative account that could explain this pattern of interference. If all the children were recalling the same integrated representation then, whatever are effects of repetition (or interview) on this representation, the level of interference would have been the same for both groups. Thus, if any additional experience with an event is absorbed by a GER, or if deviant items are ignored during confirmation, then recall would have produced a high level of interference for both groups as the new details would have been lost; alternatively, if new experiences replace the old (Loftus, 1975; Loftus, Miller & Burn, 1978), then no interference would have been expected in either group. The data showed both predictions to be simultaneously correct therefore neither of these hypotheses can be true. New material was not lost, nor was old material replaced; different experiences of the event (either as an event or as interview) were represented in different sets of records, and whether or not interference
occurred depended on the records that were accessed at the time. In the ‘interview’ group’s 3rd interview, both the recency of the 2nd interview and the similarity in the contextual information (i.e. interview setting) led to the retrieval of the records of the 2nd interview which contained the interfering information; in contrast, the records accessed by the children in the ‘event’ group were the most recently formed records of the 2nd event - these set of records were also the only set of records which would not have contained the interfering information from the 1st event.

**Free vs Total Recall**

Large differences between free and total recall were obtained in all the interviews. There were no interactions between this Recall factor and the other factors to suggest that the observed differences varied with the number of exposures to the event, or with the number of interviews. These results clearly illustrate how the magnitude of children's memory is undermined by the processes supporting free recall performance, i.e. chaining. Thus, due to restrictions on their ability to chain records, the children were not able to access the event in its entirety in response to a single general cue. The information they recalled during the free recall phase was restricted to the information in the record triggered by that single cue, but once this information was exhausted, they made no further attempts to retrieve additional information although such information was clearly available. Access of additional information then depended on the provision of cues as a substitute for chaining.

**Event repetition**

I suggested in the Introduction that familiarising children with an event should increase their knowledge of event type (representational knowledge), which, in turn, should increase the parser's relative speed of processing and reduce the degree of segmentation. It was hypothesised that this should lead (a) to an increase in the total amount recalled, as less information would be lost at the interpretation stage; and (b) to an increase in the amount of information elicited by a single cue (increase in free recall), as more information will be incorporated into a single record. Repetition of the event led to an increase on both these measures. However, the interactions between the Group factor and the other factors that were predicted for the first comparison (when the groups differed in terms of number of exposures to the event) were not found. The absence of interactions in this first comparison suggests that interviewing led to similar improvements in recall as those predicted for event repetition.
5.9.2 Event Repetition vs Interview

ANOVA1\(^{12}\) showed a significant increase in free and total recall for both groups, but no interactions to suggest that these increases were larger for one group than they were for the other. Since the ‘interview’ group in this comparison had not yet experienced the event a second time, the improvement in their performance can only be attributed to their 1st interview experience and to the records that were created during this experience. Thus, the improvement in the ‘interview’ group’s performance suggests that the 1st interview session resulted in the formation of (secondary) records that were larger than the primary records that were created during the actual experience, and that the children were recalling these (secondary) records during their 2nd interview rather than the primary records of the 1st event.

In contrast, the improvements in the ‘event’ group’s performance are directly linked to event repetition. The absence of interference in this group’s accounts of the 2nd event indicates that the children in this group were recalling the discrete set of primary records that were created during the 2nd event. While there were no significant interactions in ANOVA1 it can be seen in Table 5.5 that the increase for the ‘event’ group was somewhat larger (13.64 to 17.17) than the increase for the ‘interview’ group (13.18 to 15.27). These differences between the groups were reversed in ANOVA2 with the balance of the difference now shifting in favour of the ‘interview’ group (13.18 to 18.55). The additional improvements in the ‘interview’ condition could have resulted either from the presentation of the 2nd event, or from the 2nd interview producing a similar increase in recall as the 1st. The pattern of interference suggests that the improvement in the ‘interview’ group’s 3rd interview was incremental, resulting from both the 1st and 2nd interviews - not from event repetition. Thus, the data from the ‘interview’ condition showed that interviewing, as well as event repetition, produced an increase in the amount recalled. However, the dynamics leading to improvement in this condition are independent of those associated with the improvements in the ‘event’ condition.

Interviewing does not improve recall by increasing the parser’s relative speed, since the parser is assumed to be involved with the processing of actual experiences. Interviewing, however, could reduce the degree of segmentation, and thus improve recall, by reorganising existing information. Like the story in Wilkinson’s (1988) study, it could provide a base for

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12 ANOVA1 refers to the set of ANOVAs comparing performance between the 2nd recall of the 1st event in the ‘interview’ condition, and recall of the 2nd event in the ‘event condition, and ANOVA2 refers to the set of ANOVAS comparing performance after the 2nd event in both conditions.
a single record (or at least for a smaller set of records). It could also improve organisation by making causal-temporal links explicit. Since the interview questions in this design followed the same sequence as the event, causal-temporal links between episodes or actions could be made explicit during the interview and thus provide the children with the appropriate verbal tags with which to describe such links in the future. Alternatively, these causal-temporal links could be incorporated as new items of information. For example:

Q. "What did you do with the balloon after you burst it?";
A. "Don't know";
Q. "Did you have to put it into something?"
The link between letting the air out of the balloon and then putting it into something is made explicit. If this link was not represented, it can now be encoded as new information; if it was represented but the child could not verbalize the connection (possibly because 'after letting the air out' could mean anything that has happened from that moment on) the before and after link could now be available to her.

Interviewing may also improve recall by introducing new information, and by verbally labelling visually represented items. The interview questions were detailed, and answers were given if the child could not recall the item herself. Consequently, all of the items to be remembered were mentioned in the interview. As a result either new items could be encoded as new information, or items that were encoded but could not be verbalized could now be given a verbal tag. For example some children were not familiar with the word 'gold', but they could tell that the colour of a gold ring was the same as the colour of the balloon. Giving that colour a name during the interview would enable the child to verbalize it in subsequent recall trials.

An interview then, may improve recall by reorganising existing information. It may also improve recall by introducing new material. However, the free recall data in conjunction with the items per utterance analysis suggests organisation as the main contributor. Free recall scores are interesting because they provide some indication of the size (amount of information) of records in young children. This is not true for adults, whose ability to chain records would allow them to elicit information from more than just one record with a single cue. The free recall data indicate that both event repetition and interviewing resulted in some increase in record size. However, the increase in the 'interview' condition was associated with improvements in structure (item per utterance), whereas the increase for the 'event' group was independent of such improvements.
The items per utterance analysis revealed a significant increase for both groups in ANOVA1, but no differences between the groups, and an interaction that failed to reach significance (on a two tail test). However, the improvement for the 'event' group was almost negligible (from 1.89 to 2.16 items per utterance) in comparison to the improvement in the 'interview' group. (1.44 to 2.69). This tendency in ANOVA1 was stronger in ANOVA2. Although there were no differences between the groups, the interaction between the Group factor and the Interview factor was significant. The 'interview' group produced significantly better structured accounts than the 'event' group. Structure in this condition steadily improved from the 1st to the last interview (1.44 to 2.69 to 4.25). This improvement in structure would have led to the observed increase in the free recall scores for this group. On the other hand, the increase in the free recall scores for the 'event' group would have resulted from an increase in the efficiency with which event information is processed. Thus, in both conditions an increase in free recall, or record size, indicates a reduction in degree of segmentation. However, reduced segmentation in the 'interview' condition was linked to organisation, whereas reduced segmentation in the 'event' condition was linked to an increase in the parser's speed.

The results from the items per utterance analysis in conjunction with the free and total recall data suggest two parallel paths for improvement, one associated with primary records (the size of) and actual experiences, and the other with secondary records (organisation) and the recollection of experiences. Generally it seems that repetition of an event has more beneficial effects on the amount recalled, while interviewing produces better structure. The different effects of repetition and interviewing are illustrated in the following example:

**Interview condition - Dyco (4 years and 4 months)**

**First interview**

Exp: Can you tell me about it?
Dyco: Yes, we put the red balloons in the bag and I went here (meaning the quiet room). (4 items).

Exp: Anything else?
Dyco: That is you in there, you gave me a balloon and all the children were laughing. (2 items).

3 items per utterance; total recall 15 items.

**Second interview before 2nd event**

Exp: Can you tell me about it?
Dyco: Mickey Mouse was in the toilet. You sat in there and I
Mickey’s Balloons

| got a balloon and then I went here (quiet room). |
| 5 items per utterance; total recall 21 items. |

Third interview after 2nd event

Exp: What Happened?
Dyco: Mickey Mouse was going to the bathroom and I put this thing off and it go ‘pschew’ and I put the balloon in the bag (interfering item from the 1st event). It was a Donald Duck in it. Last time you was in there and I was opening the box with a key and there was he and all the children were shouting.

11 items per utterance; total recall 22 items

The structure progressively improved from one interview to next: from 3 to 5 to 11 items per utterance; recall also improving progressively: from 15 to 21 to 22 items recalled.

Event condition - Sean (4 years)

First interview
Exp: Can you tell me what happened yesterday?
Sean: Mickey Mouse came, I burst my red balloon and I get a grey balloon.

6 items per utterance; total recall 17 items.

Second interview after 2nd event
Exp: Can you tell me what happened?
Sean: Mickey lost his dark blue balloons after we had lunch, then we washed our hands and burst our balloons, our blue (correct item), dark balloons and got a Mickey Mouse sticker (correct item). (7 items)

Exp: Anything else?
Sean: And I had a sticker from you. And I turned the key, and then I opened it and then I have the sticker and I go to have a quiet time. (5 new items)

6 items per utterance; total recall 24 items.

With Sean we can see a large improvement in recall from 7 to 24 items after the 2nd event, but no improvement in structure - 6 items per utterance in both cases.

To summarise, event repetition improves overall recall by increasing the parser’s relative speed of processing, which results in less loss of information and reduced segmentation; the former leading to an increase in total recall and the latter to an increase in free recall. An interview, on the other hand, does not improve the parser’s speed, but it can reduce the degree of segmentation by reorganising the structure of existing information, and it could also introduce new material.
5.9.3 An Overview of ‘Mickey’s Balloons’

Figure 5.6 illustrates the relationship between events, interviews and records.

Figure 5.6

*The records associated with each event and each interview*

![Diagram showing the relationship between events, interviews, and records]

By the end of the 1st event there is a set of primary records representing this experience. During the 1st interview, these event records are accessed according to the particular description being formed. The information accessed is organized and mapped into the interview records. The resulting records will include information from the event records in a more processed form, and possibly a few new details. At the end of this stage there is a set of records representing the event and a set of records representing the interview. The headings linked to these sets of records are similar as they all include information about the visit of Mickey Mouse. Therefore, the most recently created records will be accessed, unless a more discriminatory description is formed.

In the session context the first question to assist recall is "Can you tell me what happened when Mickey Mouse came to visit?" A description formed using this cue could
potentially match any of the headings containing information regarding the 'Mickey' event. The ‘Mickey's visit’ description will therefore access the most recently formed record. The 2nd interview for the ‘interview’ condition will thus access the records formed during the 1st interview. The evaluation process will accept these records, as the information they contain would satisfy the task specification, i.e. providing the experimenter with details of the event. As the 2nd interview progresses, a new set of records is formed which will include information from the 1st interview in addition to any details (items or links) that were available in the 2nd interview and that were not attended to previously.

On presentation of the 2nd event, the most recently created records are accessed: the 1st interview for the 'event' group and the 2nd interview for the 'interview' group. However, interview records will fail the evaluation process, as they will not contain the appropriate information with which to interpret the current experience. Moreover, as the event progresses, the additional perceptual information (e.g. colours, shapes etc.) will enable more discriminatory descriptions to be formed. Thus, during the 2nd event, the primary records of the 1st event would be retrieved. These records will enable the child to attend to details that were not attended to during the 1st event, and recognize the details that deviate. For example, when children were asked during the event what they expected to find in the treasure box, they would answer 'balloons' and then be surprised when they found out that Mickey Mouse stickers were in the box instead. The primary records that are created during the 2nd event will include new details that were picked up the second time around as well as relevant details from the old records, but they will not include the interfering items from the 1st event, as these would be recognized as being deviant and would therefore be considered irrelevant to the current experience.

In the interview following the 2nd event, the records retrieved for recall will be different for the two groups. In the 'event' group the records containing information of the 2nd event will be retrieved, since they would be the most recently formed records. Accounts based on these records will be more detailed than previous accounts, and will not include the interfering items from the 1st event. However, in the ‘interview’ group there will be two sets of records competing in terms of recency, as the interview records and the 2nd event records were created on the same morning. In this case the context effect of the interview setting will give priority to the 2nd interview records. Accounts based on these records will be better structured, they will include more details, and since the records are based on information of the 1st event, they will include the interfering items. Being able to recall correct items as well
as interfering items may be a reflection of the competition between the two types of records. Access may be alternating between the two throughout the interview.

How would the GER model account for these results? According to my reading of the model, events and interviews will be fused together as they are all instantiations of the same event. By the last interview, the previous experiences, three for the ‘event’ group and four for the ‘interview’ group, would have been expected to form a script for the ‘Mickey’ event. Accounts of this script would be expected to be in a generalized form rather than detailed accounts. This was not the observation. The GER model would predict that structure would improve as the script becomes more schematized. In this case the lack of structure found in the ‘event’ condition could not be explained. And with regard to interference, if the 2nd event was absorbed by the GER, or if the deviant items were ignored during confirmation, then recall protocols would be expected to contain high levels of interference as the new details would be lost; if the new details replaced the old information, as Loftus et al (1978) have suggested, then no interference would be expected. I found both predictions to be simultaneously correct therefore neither of these hypotheses could be true. Material was neither lost nor replaced, different records contained the different details, whether or not interference occurred depended on the records that were accessed at the time; event records in the ‘event’ condition or interview records in the ‘interview’ condition.

Addendum

As I have subsequently discovered an interview of an event not only produces interference but also leads to an increase in the amount recalled. Consequently, an improvement in the ‘event’ group’s performance after the 2nd event could, in principle, be attributed either to their additional exposure to the 2nd event or to their 1st interview. The pattern of interference suggests the former, however, had I anticipated an improvement due to an interview prior to testing, I would have had to include an additional comparison to deconfound the ‘event’ and the ‘interview’ factors. In this comparison children would have been interviewed only following presentation of the 2nd event. Thus, one group of children would have been exposed to the 1st and 2nd event (without the intervening interview, i.e. ‘interview1’), and then tested for recall of the 2nd event; and another group would have been exposed to the 2nd event only. Any differences between these groups could then be solely attributed to event repetition.

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12 No explicit statement has been offered as to the status of interviews about an event in the overall generalized representation of the event. However, since schema models generally assume that (a) schema are involved in all processing that require perception and memory; (b) schema are modifiable; and (c) there is no duplication of information, then it must be the case that a schema that is used during a recall session, e.g. an interview, may be modified and/or strengthened by the interview, particularly if new information becomes available. It cannot be assumed, however, that interview sessions of a specific event type would be represented in a separate generalised structure, since the information in such a representation would be a duplicate of the actual GER.
6. PULLING SMARTIES OUT OF A BAG

6.1 An overview

In Chapter 4, I discussed the consequences of younger children’s greater limitations in capacity would have on their processing. I suggested that their more limited capacity will result in a greater loss of information, and in greater demands on retrieval due to the fragmented nature of processing. I did, however, maintain that with the appropriate environmental support both these failings could be corrected. The data from the 'Mickey' study showed that environmental support in the form of cues helped children access their representation of an event more completely, independent of the number of records that may have represented this event. It also demonstrated how a single repetition of an event can lead to greater retention of event information. This chapter will specifically focus on the issue of information loss, but this time it will be approached from a different perspective. In the 'Mickey' study my aim was to produce a general increase in the amount recalled but I could not predict in advance which information would be lost and which would be retained, neither could I determine whether a new item of information retrieved in subsequent recall sessions was indeed new, nor whether it had been encoded from the start and was only expressed subsequently. In this study it can be predicted in advance which information is lost and my aim will be to help children retain this particular information.

The study is based on a well-known task within the theory of mind domain - the Smarties task (Perner, Leekam & Wimmer, 1987). In the Smarties task, children are typically presented with a Smarties tube and asked what they think is inside. When the children have given their response, the true, and unexpected content of the tube - a pencil - is revealed. The pencil is then returned to the tube, and the children are asked what they had thought was in the tube when they first saw it. Strikingly, the majority of 3-year-olds forget their original thought (belief) about the contents of the tube (Smarties), and rather insist that they had always thought that the tube contained a pencil. The ‘Smarties-Bag’ (SB) task used in the present study is a
variation on this theme, specifically modified to help children remember their original belief. We already know from the 'Mickey' experiment that the repetition of an event leads to better retention. One modification to the original design will therefore include repetition. Another modification will involve the creation of an accessible record that will contain the target information, i.e. the Smarties response. The rational for these modifications will become clear when I analyse the Smarties task in relation to the model. I will start by defining theory of mind, and then I will outline the explanations for the failure offered within this domain. I will proceed to analyse the Smarties task as a memory task and discuss the ways in which children's performance may be improved. Finally, I will report the SB study which will demonstrate once again how children's failure can be turned to success with a little help from the environment.

6.2 Theory of Mind (ToM)

Theory of mind (after Premack and Woodruff, 1978) refers to the ability to interpret behaviour in terms of mental states such as beliefs and desires\(^{13}\). The successful application of this mental attribution framework requires an understanding that the mind is representational. Three-year-olds are able to judge correctly that a character can touch a bike only if he possessed it but not if he thought or dreamed of it (Wellman & Estes, 1986). This suggests some conception of the representational nature of the mind as it shows an understanding of the nonidentity relationship that exists between real and imagined situations. However, is this understanding indicative of a competent theory? A competent theory of mind would enable an individual to attribute mental states to others that differ from his own; it would also enable an the individual to understand that mental states (his and others) can differ from reality. False belief is a special case of a dissociation between a mental state (belief) and reality, and tasks creating states of false belief situations, such as the Smarties task, were developed to test the competence of children's 'theory of mind' (ToM). Typically, three-year-old subjects fail false-belief tasks; specifically in the Smarties task, about 70% of children younger than four 'forget' their original belief about the tube's contents (Smarties) once that belief is violated by the

\(^{13}\)As a theory of mind term, mental refers to any representation of a situation that is not a direct product of perception. This will include representations of imagined, desired, pretence or belief situations. The case of representations of past experience, however, is ambiguous. Within the theory of mind domain, a recollection of the past is not considered mental in the same way as, for example, a belief is mental, presumably because a representation of the past is (or was) a product of perception, whereas a belief, desire etc. are (and always were) internal states. However, from an information processing point of view, when a representation of a (perceptual) past experience is recollected it is internally generated and it is therefore mental. Thus, as long as it is borne in mind that the term mental has a narrower use in the theory of mind domain, confusion can be avoided.
actual reality (e.g. Gopnik & Astington, 1988; Perner, Leekam & Wimmer, 1987; Sullivan and Winner, 1991). Within the theory of mind domain, explanations for this failure are divided between two conceptually different approaches. One approach attributes the failure to the young child's limited representational capacities - ToM competence (Flavell, 1988; Gopnik & Astington, 1988; Perner, 1988; Wellman, 1990), and the other to limitations in general processing skills that attenuate children's true representational ToM competence - performance (Freeman & Lacohee, 1995; Leslie, 1988, 1994; Mitchell, 1994; Wimmer & Weichbold, 1994).

The first class of explanation locates the problem in the child's theory of mind. Proponents of the ToM competence approach focus on children's representational ability as the source of the difficulty in false belief tasks. Young children fail false belief tasks because their ToM has not yet reached an adequate competence level that will enable them to understand and/or represent a belief state and this is independent of whether the belief is true or false. The explanations, however, differ as to the exact nature of this deficit. All ToM competence theories view the final state of ToM development to be a representational understanding of the mind. They do however differ in terms of the specific deficits they attribute to the younger child at the early stages of ToM development. In the next section I will focus on the main explanations within this approach, and in particular on Perner's account.

The performance class of explanations, on the other hand, reject this notion of limited representational capacities. As for representational capacities, young children's ToM is assumed to have already reached an adequate competence level. However, ToM performance is thought to be limited by general processing skills that regulate the way in which belief-relevant information is processed. On this view then, it is not that 3-year-olds have a problem with understanding or representing beliefs, but rather that there are limits in the efficiency with which the 'belief' concept is utilized. Performance accounts vary with regard to the particular skill each is emphasising as the possible limiting factor. Since the primary interest of these researchers remains within the theory of mind domain, their information processing accounts are not furnished with much detail. I will therefore mention them mostly in brief.

6.2.1 ToM Competence Limitation and the Smarties Task

The general consensus among proponents of limitations in ToM competence is that children younger than four have not yet reached a certain final stage in the development of ToM which will enable them to understand and represent certain mental states such as false
beliefs (Gopnik & Astington, 1988; Perner, 1988; Wellman, 1990). Explanations, however, vary with regard to what type of 'mental' understating is available to, or lacking in children prior to that final stage of competence.

Wellman (1988, 1990), for example, believes that 3-year-olds can explain behaviour in terms of mental states, however, he suggests that, at this age, mental states are direct copies of reality. A child as a 'copy-theorist' assumes no internal processes by which beliefs - whether true or false - may be acquired. Nevertheless, as long as the mental representations linked to her predictions reflect the reality, as with imagining, a child who is merely a 'copy-theorist' will be able to predict behaviour even if she has no conception of the mind as an information processing system. However, a false belief situation that requires the child to represent a single state of the world in two different ways would be problematic because the source of the difference between such representations is in the mind not in the state, and since the child, who is a copy-theorist, has no conception of the mind as an information processing system, she will not be able to resolve the duality. Clearly, this deficit would be expected to generalise to any situation that leads to representational duality. Yet, young children's apparent understanding of pretence (Flavell 1988, Flavell, Green & Flavell, 1986; Gopnik and Slaughter, 1991; Leslie, 1987), and deception (Chandler, Fritz & Hala, 1989; Hala, Chandler & Fritz, 1991; Sullivan & Winner, 1993) does not conform to this expectation. The ability to pretend or deceive not only necessitates dual representation of a single state, but also requires some understanding of the ways in which the alternatives differ from reality, otherwise the goal of pretence or deception will not be achieved. Children engaged in these behaviours can exploit their 'copies' of reality (e.g. a banana) to create an alternative representation (e.g. a phone), but then, the resulting alternative (the pretence representation) which is based on manipulation of a 'copy' cannot be a copy (e.g. a banana phone). Thus, the ability to have an alternative 'mental' representation alongside a copy of reality is not strictly absent in young children.

Gopnik and Astington (1988) have pointed out that it may not be so much a problem of duality as a problem of the conflict between the representations. They have suggested that in the false-belief task young children find it difficult to resolve the conflict between the original representation of the believed reality (Smarties) and the actual reality (a pencil), and instead of changing their original representation as a way of resolving the conflict they simply overwrite it with the newly established reality. Gopnik and Astington account makes no reference to the type of mechanism or process that may be responsible for the ability they claim.
to define. Their account, therefore, could only be seen as a more finely tuned description of the failure rather than an explanation of its underlying cause. The actual concept of representational change is in itself elusive and ill-defined, and I have discussed the ambiguity surrounding its definition in Chapter 1.

"...We might capture this fact by saying that as adults we have representations of objects in the world, that those representations change, and that we represent the fact that those representations change. All creatures that represent the world at all change those representations. However, human adults have the additional ability to represent their past representations of the world and to contrast them with their present representations. They can understand the processes of representational change itself." (Gopnik & Astington, 1988, p. 26).

To reiterate, the concept of 'representational change' is ambiguous for two reasons. First, it confuses between structure (of representations) and process (operating on representations): It may be understood to refer to both changes in the contents of representations (structure) as well as to the representation of changes (process). Second, it is not clear whether 'representational change' refers to changes in representations or to changes of representations. Thus, is it the case that young children cannot change the status (or the truth value) of the original 'Smarties-in-tube' representation (i.e. they cannot change their original representation of 'Smarties-in-tube' from a reality representation to a belief representation); or, is it the case that children cannot understand how their representation regarding the contents of the tube changed from 'Smarties' to 'pencil' because, unlike adults, they cannot compare and contrast between these representations? The latter interpretation - i.e. that children fail because they cannot contrast between their past 'Smarties' representation and their present 'pencil' representation - presupposes that there is something inherently different between these representations that can be potentially detected, although it is not detected by children. Whereas in the case of changing the status of the (Smarties) representation (from reality to belief), the difference must be derived in retrospect and imported into the representation. I view these two types of 'representational change' as fundamentally different types of deficit, one associated with the formation of (belief) representations and the other with an ability to reflect on representations in retrospect. It is not clear to me which of these Gopnik and Astington advocate.

While Gopnik and Astington account does not offer a satisfactory causal explanation for children's failure on false belief tasks, it does articulate the problem a little more. As they have suggested, it is not that children cannot have dual representations of a single referent, but
rather, children cannot resolve the conflict that is part of the duality in a false belief situation. Perner (1991) goes further than Gopnik and Astington in that he defines the mechanism that underlines this 'conflict resolving' ability that is absent in 3-year-olds.

**Perner's Situation theory**

Perner (1991) believes that children younger than four can form representations, even counterfactual ones, but they cannot model the process of representation - they cannot metarepresent. It is only when children reach that stage of competence when they can metarepresent, that they can begin to resolve the conflict between competing representations. Perner's account is the most comprehensive, and best specified ToM competence account, and I will discuss it in a little more detail.

Perner uses the term 'representation' to refer to representational medium, or representational process, but not to representational content. As a concept, 'representation' to Perner is something that stands in a 'representing relation' to something else:

Medium ----->representing relation -----> content

( photo) (the object in the photo)

The photo is the representational medium (or a representational process), what is depicted in the photo is the representational content, and the relationship between the photo and the real object (the referent) is the representing relation. The representing relation shows not that the referent is represented but that it is represented in a certain way (as a photo). This distinction between representing and representing as, provides a way of discriminating between the 'meaning' of different representations of the same referent when the same medium is used, i.e. the 'sense' in which a referent is being represented as being a certain way. A representation of the 'sense' Perner terms 'metarepresentation'. To clarify this point Perner uses the following example (Figure 6.1).
In this example, the lineman (A) is the referent; the painting of the lineman is the representational medium (B), and the lineman in the drawing is the representational content; painting is the representational process, and the drawing of the drawing process of the lineman is the metarepresentation (C). In other words, metarepresentation is a representation of the representing process, it shows the representational links between the drawing of the lineman (the representation) and the linemen (the referent), in other words, it shows how the model (B) relates to the reality (A).

In a false belief situation, such as the Smarties task, the referent (A - the tube's contents) is the same, but there are two different representational contents (Smarties and a pencil); the representing relation shows how these representational contents (Smarties and pencil) are related to the referent (the tube's contents) in the former case as a belief and in the latter case as a reality. Metarepresentations, however, are only necessary to break away from reality, reality itself does not require a metarepresentation. Perner suggests that organisms have evolved perceptual systems as a reliable source of information about the world, and that thus perception imposes itself as reality, therefore, there is no need to mark a perceptual model as real because by definition it is real. A representation, or a B model then, can be seen as a default reality model (unless, as we will shortly see, it is marked as an alternative model of reality). A problem, however, arises when the B model is a mental, rather than a perceptual, product (e.g. Smarties). It is then that a metarepresentation (e.g. belief) would be necessary to reveal how this B model (Smarties) is related to reality (e.g. as a belief). Thus, the difference between 3- and 4-year-olds is in their metarepresentational abilities. Three-year-olds cannot metarepresent, and they will therefore have two conflicting B models of reality; the less recent
of which (the Smarties model) will either be replaced by the more recent model, or will become inaccessible. In contrast, 4-year-olds have the ‘conflict-resolving’ device – the metarepresentation – which indicates to them that one B model is a mental model, they will therefore have a B model of reality and a C model of belief. (As Pemer’s account is not a computational account, it is not entirely clear from his formulation whether the original Smarties representation is represented as a belief (a C model) from the start or in retrospect, and whether 4-year-olds will have one or two B models).

Now we come to the question of pretence in the absence of metarepresentational abilities. Three-year-olds cannot represent belief states (metarepresentations) nevertheless, they can pretend because, according to Pemer, in pretence the child does not need to understand thought as a representation of reality. Pemer’s claim is that with belief the child must understand thought (the belief) as a representation of (some) reality to understand that the content of that thought (belief) may be either the same as or different from the present (perceptual) reality; whereas with pretence this is not necessary, because the pretence situation is not and never was real, therefore the dissociation that exists in a false belief task between the content of a representation (model B of some reality, i.e. Smarties) and reality (the referent) does not occur.

The validity of Pemer’s argument for pretence in the absence of metarepresentational ability, largely hinges on his definition of pretence. Pretence according to Pemer can refer to two different kinds of substitutions:

"It is not clear which substitution Jacqueline intended when her father observed her treating a piece of cloth as her pillow. Did she mean to behave "as if it were" her pillow, or did she want to use the cloth "as a symbol" for her pillow? One thing is clear, though: the two substitutions are not the same, since acting as if something were something else is different from using one thing to represent another.... My argument is that acting-as-if provides an adequate interpretation of early pretend play." (Pemer, 1991, p. 53).

In Pemer’s view a metarepresentation will be necessary only if Jacqueline was using the cloth to represent the pillow. For this type of pretence, Jacqueline would have to understand how the cloth (referent) is related to the pillow (representational content). However, if Jacqueline was using the cloth as if it were a pillow then metarepresentation will not be necessary. Here she need only mark the pretence situation as a hypothetical situation and this will be sufficient to differentiate between the pretence model and the reality model:

"To execute the pretence, Jacqueline has to switch action control from the reality model to the as-if model....The theoretically important question is what
the relationship between these two models has to be. My answer to this question is that the two models simply represent two different situations: the real situation and a hypothetical situation". (p. 54).

Essentially, I understand this to mean that young pretenders are in effect creating a hypothetical referent. Thus, in both types of substitution, the pretence would result in two different B models. However, instead of resolving the duality of their B models by representing the representing relation between the referent (the cloth) and the contents of the pretence representation (the pillow), children in the as-if situation are creating a hypothetical referent, and they simply mark the representation linked to this referent as an alternative non-real B model. This alternative B model can then coexist alongside the reality model without any conflict. The crucial point here is that in this type of pretence children do not have to understand the non-real model as a mental creation.

It may be a problem of incommensurability (Kuhn's definition), but I am not clear how is it possible to create (and mark) a hypothetical mental model of reality without understanding how this model relates to reality, and how is it possible to understand this relationship, without understanding the representational links (the representing relation) between real and hypothetical. Wouldn't the choice of the pretence object be governed by some such understanding? In other words, are we as likely to see a child pretending that a cloth is a phone or that a banana is a pillow?

Generally, I agree with Perner's line of argument, but not with his assumptions regarding the differences between pretence and belief. We can all agree on two premises: (I) false beliefs and pretence are the same in so much as both lead to representational duality; (II) false beliefs and pretence are also different since 3-year-old can do one but not the other. However, I disagree with Perner's views regarding the source of the difference. Perner correctly points out that when there is a potential conflict between two different models (representational contents) of what appears to be a single referent, it can be resolved either from the top by understanding the relationship between these models (with metarepresentations), or from the bottom by associating each with different referents (real and hypothetical) (although I still have my reservations regarding the creation of hypothetical situations without metarepresentation). Based on his assumptions regarding the developmental differences between 3- and 4-year-olds ToM abilities, and on premise (II), Perner then associates one solution with false beliefs and the other with pretence.
However, just as pretence can be associated with either solution (depending on which definition of pretence is chosen) so can false belief. In fact, the false belief situation makes an even stronger case for differentiation on the basis of the referents, since the two models here are associated with different referents: one with specific reality and the other with general reality. Alternatively, since Perner assumes that 3-year-olds can differentiate between models according to time (past vs present) an even easier option would be to associate one model with the present (test) experience and the other with the last (past) experience with a Smarties tube. Why is it then that children cannot differentiate between models according to whether they relate to specific or general reality, or according to time? My answer to this question, which I believe Perner would agree with, is that it all depends on which comes first - the model or the referent. In the false belief situation, the mental model is already there and the child must go from the mental model to the referent, whereas in pretence the child goes from the situation that she decides to create (the referent) to the mental model. Perner's claim, as I understand it, is that in the model to referent route, it is essential to understand that the model is mental, and this requires metarepresentations, whereas in the referent to model route this is not necessary. Still, this argument would be more difficult to apply to temporal differentiation: if children can mark a model as past, then they should be able to resolve the false belief situation without implicating belief states, by simply marking the less recent model of 'Smarties in the tube' as the last past experience with Smarties tubes, and the model of 'pencil in the tube' as the present experience. Children clearly do not do this, however, and in my view, the reason is not related to metarepresentations or to belief states, although, it is related to the marking of representations.

I too believe that there is a problem with the model to referent route, but the source of the difficulty I identify computationally with on-line vs off-line marking (of representations) rather than with metarepresentations (or belief states). The computational conditions in pretence and false belief are different in that in the former the non-real situation is marked on-line, and in the latter it can only be marked as a general reality (or a belief, or a past experience) off-line - in retrospect. Thus in pretence, children know that they are working with two different referents (real and hypothetical) at the time the representations of this situation are formed, and they can mark them accordingly as they are formed. In the false belief

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14 To avoid confusion, it should be pointed out that although a recollection may be viewed by some, including myself, as a mental creation, to Perner a recollection is not mental in the same way that beliefs, pretences or desires are mental.
situation, on the other hand, they would only find out subsequently that another referent is involved, but by then the original (belief) representation had already been formed and left unmarked, and the only way to resolve the conflict at this point (other than overwrite the belief representation) is by re-evaluating this representation and marking it in retrospect. Young children, as I have subsequently found out, cannot mark their representation in retrospect, which may be the ability Gopnik and Astington have been alluding to with their notion of representational change, but, I would very much doubt that 4-year-olds and adults are endowed with such an ability. At best, 4-year-olds (possibly) and adults (certainly) will be able to reflect on their thought processes and re-represent their original belief. However, in my view, older children and adults do not resolve the false belief situation by either changing their original representation or inferring it; rather, I suggest, they have no conflict to resolve because they spontaneously mark the source of their representations at the time those representations are formed. In contrast, young children do not mark the source of their representations, unless they are explicitly aware of a duality - as with pretence. My explanation departs from that of Perner's in that I would predict that if children could be made aware of the potential duality and mark their belief representation at the time that representation is formed, they would be able to pass a false belief task; and I propose that this could be achieved by a simple repetition. I will discuss this and related issues in more depth in the next section, but at this point I simply wished to introduce my view in relation to Perner's account because the rationale is similar even if the basic assumptions or conclusions are not. Thus, I accept Perner's analysis of the problem faced by children in the false belief situation, but unlike him I do not see that there is anything special about beliefs. With regard to the status of beliefs I adopt a ToM performance approach - and in particular Leslie's (1988) account.

6.2.2 ToM Performance Limitations and the Smarties task

In this approach young children's ToM is assumed to have already reached adequate competence levels, but their performance is thought to be attenuated by general process skills that regulate the way in which belief-relevant information is processed (Freeman & Lacohee, 1995; Leslie, 1988, 1994; Mitchell, 1994; Wimmer & Weichbold, 1994). Developmental changes in these skills mark the difference between failure and success on false belief tasks. Explanations differ with respect to the particular skill each emphasises as the possible limiting factor. Within this class of explanation, Leslie's provides the best articulated alternative model of ToM.
Leslie (1988, 1994) views ToM as an innate, domain specific ability that becomes functional at about 18 months of age as evidenced by the emergence of pretend play. He argues that once children can engage in pretend play, they are able to represent propositional attitudes (ToM representations, also referred to as metarepresentations) of which beliefs (true or false) are just another example. The difficulty with the Smarties task, Leslie suggests, is not with representing the attitude concept of belief, but rather with the selection of the appropriate input (i.e. 'past experience with Smarties tubes' vs 'test experience') as the basic premise for making an inference about the belief. Leslie proposes that this inference is carried out by a specific processor which he termed the Selection Processor (SP). In Leslie's view, a poorly developed SP is the cause for the failure on the Smarties task, and, as Leslie (1992) and Zaitchik (1990) demonstrated with the 'photo' task, any other (non theory of mind) task that requires selection for an inference process. Thus, 3-year-olds fail the 'think' test question because their poorly developed SP wrongly selects 'test experience' as the basic premise with which to make an inference about their belief, and as a result they make an incorrect inference (pencil in the tube). On the other hand, 4-year-olds use the appropriate input and therefore answer the question correctly. I would agree with Leslie that, in principle, if the original 'Smarties' representation had been lost then reconstructing and inferring the original response is an alternative way to resolve the task. However, in practice, I doubt that young children would have the capacity to resolve the task in this way, if they do not have the capacity simply to remember their response.

A similar view is held by Wimmer (Wimmer, 1988; Wimmer & Weichbold, 1994). However, he focuses on informational access as the principal skill that limits performance on false belief tasks. Younger children, according to Wimmer, do have a concept of belief, but they are still learning about beliefs; more specifically they are still learning about the role information plays in causing beliefs. Thus 3-year-olds fail false belief tasks because they are unable to appreciate the origins of their representations, as they do not understand the link between events in the world and beliefs, and therefore do not understand the informational conditions which lead to false beliefs. Since young children do not causally link the belief about the content of the experimental tube and their previous experience with Smarties tubes, they cannot maintain the belief in the test situation. I, however, am not certain whether children's inability to link their belief to their previous experience is a problem of actually making the causal link or whether it is a problem of capacity that prevents them from maintaining all the relevant information that is necessary to make that link.
A different perspective has been offered by Mitchell (Mitchell, 1994; Mitchell & Lacohee, 1991). Mitchell proposed that young children's true ToM competence is masked (or attenuated) by a bias to match beliefs (representations) to physical rather than psychological events. In other words, if children have two representations, one of which they must choose as a belief representation, they would prefer to choose (as a belief representation) the representation that has a physical counterpart in the world. To show that unmasking children's ability to represent a false belief is possible providing that the belief is registered in "an event that leaves a physically enduring trace in the world", Mitchell and Lacohee (1990) added a 'posting' stage to the original 'Smarties' paradigm. In this experiment, after the children stated what they thought was in the Smarties tube, they were asked to post a picture of what they thought the content was, i.e. a picture of Smarties. At test they were asked: 'when you posted your picture in the postbox what did you think was in the tube?'. In this condition most children judged correctly that they had thought the tube contained Smarties when they first saw it. Children could remember their old false belief inasmuch as they could remember a physical representation of it. To show that the success on the task was not simply due to solving the problem of communicating exactly the point in time to which the experimenter was referring, an additional condition was included. In this condition the children were asked to post a representationally irrelevant picture (a cartoon character). There was a small non-significant improvement in this condition, but on the whole children still failed to give the correct response. The authors concluded that, since the posted picture was representationally irrelevant, it could not be used as a physical anchor for their initial belief. However, it could also be argued that in the 'relevant' condition children remembered the 'Smarties' picture rather than their 'Smarties' response (or belief). This points to the main weakness with the 'reality masking' account - the physical anchor and the psychological state are inherently confounded, which makes the 'reality masking' hypothesis difficult to put to test.

In a recent paper, Freeman and Lacohee (1995) reported a series of studies based on the posting paradigm, but their theoretical emphasis has shifted away from the reality masking hypothesis to a hypothesis about inaccessibility. The failure on the original Smarties task, they suggest, is a (memory) failure to access the belief representation. Thus, the belief representation exists, but it is inaccessible:

"Yet it could be that an available record is temporarily inaccessible; and if that is the case, clearly one would expect cues to facilitate recall of episodic memory." (Freeman & Lacohee, 1995, p. 33).
And they conceptualise the differences between 3- and 4-year-olds in the following way:

"The present data suggest that the particular inferencing problem is due to a difficulty in accessing the relevant information in memory. Once 4-year-olds rectify the deficit, perhaps by an across-the-board acquisition of a concept of evidence, they pass the test without cues because they can inferentially reconstruct their reasoning....According to that argument, the cues we provided do not turn 3-year-olds into 4-year-olds for the purpose of the test but enable 3-year-olds to succeed by direct recall instead of inferential reconstruction. The reason that 3-year-olds cannot normally succeed unaided is simply because they find memory search difficult" (Morton & Bekerian, 1986; Wilkinson, 1988)." (p. 56).

With this notion of inaccessibility they go on to explain success in the relevant picture condition as inaccessibility overturned by the use of cues; that is, the relevant picture was used as the cue that helped children access their belief representation. Interestingly, in subsequent studies where the picture of Smarties was replaced by the actual object (i.e. real Smarties) children's success rate increased only marginally - from 30% to 44% correct in the relevant object condition as opposed to the 86% correct in the relevant picture condition. Across six studies, using Smarties tubes or egg boxes, and a variety of cues, the authors reported improved performance only with relevant picture cues (a picture of Smarties or eggs) but not with irrelevant picture cues or with relevant object cues. They concluded that the data supported the inaccessibility hypothesis and also revealed differences in the efficacy of cues, most intriguingly between relevant pictures and relevant objects. According to Freeman and Lacohee, these differences suggest either that pictures are more memorable than objects (although they did not report any difference between pictures and objects for the control memory question - 'what did you post?'), or more associable with thoughts than objects. It is ironic that what started as an information processing account ultimately reverted to a representational explanation to account for these differences. However, this is almost unavoidable given that Freeman and Lacohee's 'memory' explanation lacks the foundation of a theory of memory. Their notion of (in)accessibility is loosely defined, and their characterisation of 3-year-olds failure is unsatisfactory.

It is clear from the above quotations that Freeman and Lacohee neglected the distinction between memory for specific events (episodic memory) and memory for general events, as well as the developmental pattern that is associated with each. Consequently we are left wondering what type of information becomes inaccessible. Is it the episodic representation of their original Smarties response (in the test situation), or the generalised representation
concerning Smarties tubes in the world? In the first quotation the authors explicitly state the former but in the second quotation they implicitly suggest the latter. To re-iterate, in the second quotation they state that "the particular inferencing problem is due to a difficulty in accessing the relevant information in memory....The reason that 3-year-olds cannot normally succeed unaided is simply because they find memory search difficult". Well, young children find it difficult to search memory for specific episodes not general episodes; since the relevant information for an inference process would be general ('Smarties' is the general contents of Smarties tube), it should be easier for children to access this information. Therefore the problem children have with inferencing cannot be one of accessibility unless it is assumed that the generalised representation becomes blocked.

In addition to the ambiguity regarding specific and general representations, the authors appear to assume that direct recall does not implicate access. Since they assume that children can directly recall, but they cannot engage in inferential reconstruction because they have difficulty with access, the conclusion that direct recall (of an episodic record) does not require access naturally follows. However, according to Morton et al's (1985) HR framework, which Freeman and Lacohee cite, any retrieval of a record (be it specific or general) implicates access.

Finally, if as they claim, direct recall of 'episodic memory' is easier than inferential reconstruction (a claim I am in agreement with but not for reasons of accessibility), and if there is an 'episodic memory' of the Smarties task available, why then should 4-year-olds use inferential reconstruction? Maybe 4-year-olds too cannot access their episodic memory? But then what about adults, they cannot possibly assume that adults are unable to access their episodic memory. Clearly, it is either that inferential reconstruction is not used by 4-year-olds, or Freeman and Lacohee found a new developmental stage regarding accessibility between 4-year-olds and adults. Either way they still must explain why the episodic (or general) representation becomes accessible at some age, or abandon their inaccessibility hypothesis. Indeed, if the accessibility hypothesis is replaced with an availability hypothesis then Freeman and Lacohee’s data, and in particular the differences between pictures and objects, could be explained computationally. I will discuss these data in the next section when I analyse the Smarties task computationally and in relation to my model.
6.2.3 Interim Summary

In essence, the dispute surrounding ToM ability may be nothing more than a problem of reference: is ToM a domain specific or a domain general ability? If, as Leslie suggests, it is a specific module that processes information pertaining to propositional attitudes (or mental states), then young children's ToM must be competent by the time they can understand pretend play. Their failure on false belief will then be due to limitations in general processing skills. However, if one chooses to view ToM as a general meta-cognitive skill then ToM may not be competent at - or even beyond - the age of four. My main concern is not to define theory of mind. To me the Smarties task is a perfect example of a situation that results in information loss. As an event, the Smarties task is not rich or complex, yet children forget a significant piece of information. Disregarding beliefs for a moment, children forget what they had said. My concern is to identify the processing conditions that lead to this peculiar forgetting and help children remember their original response.

6.3 The Smarties Task, Memory and the Model

6.3.1 The Smarties Task Revisited

From this point on I will be considering the task from an information processing point of view, focusing on contents of buffers and records. When children are asked 'What do you think is in this tube', they invariably respond with 'Smarties'. We know that the child is consulting a record of either his last experience with a Smarties tube or a general knowledge schema concerning Smarties tubes in the world, otherwise she could not provide an answer to this question. We also know that once the child provides this response she must have already represented the current tube as containing 'Smarties'. I will used the term $t(S)$ to refer to this (episodic) representation. This $t(S)$ representation will reside in the on-line buffer until the true contents of the tube is revealed (a pencil) and a new representation of the tube as containing a pencil - $t(p)$ - enters this buffer. Now, there are three possible consequences each of which will be associated with a different solution to the 'think' question. These solutions can be termed:

(1) Direct output - if both representations continue to reside in the on-line buffer
(2) Retrieval - if the more recent $t(p)$ representation triggers transfer of the $t(S)$ into LTM
(3) Inference - if the more recent $t(p)$ representation replaces the original $t(S)$
Of the three different routes to success on the Smarties task, the least computationally demanding solution is a direct output from the on-line buffer. Clearly, if the answers to the test questions are directly available from the on-line buffer, then no further resources need to be expended on additional computation, such as iteration of the retrieval cycle or inferencing. However, successful performance via this solution would be conditional on the buffer’s capacity being sufficient to allow both tube representations to be available at the time of test. Moreover, for the solution to be correct, the representations must be differentiated along some dimension (e.g. recency, source, time), otherwise the answers to the ‘think’ and the ‘reality’ questions may be confused. My assumption is that older children and adults resolve the task this way because their processing system allows for both these conditions (capacity and marking) to be met. In contrast, young children lose the $t(S)$ representation from the on-line buffer because in their case neither condition is met. First, their more limited capacity, which dictates more frequent updating of information in the on-line buffer, will lead either to destructive update or to the creation of inaccessible records. Since the parser determines the overall organisation of event records by providing the hierarchical organisation, and by preserving the temporal structure of the event, it is in fact the parser that will determine which information will be preserved (and which overwritten) and how it will be segmented. Second, they do not mark their representations spontaneously. However, it is not that young children cannot mark a mental model because they do not understand its (mental) source, but rather they do not spontaneously include source information as part of their representations. Given that young children have more limited resources, I assume that the representations they form are as simple as the situation allows, and if the necessity to delegate resources to the creation of more complex representations (which would include source information) is not explicit in the situation (as is the case with pretence) they will not delegate.

6.3.2 Tracing the ‘Smarties’ Response

It is clear from the failure of 3-year-olds on the Smarties task, that the original representation of the tube as containing Smarties, which must have existed at least initially, is no longer available - at least not for direct access in the on-line buffer, therefore it was either updated or blocked. My hypothesis is that the original representation was updated rather than blocked.
Generally, when capacity is exceeded, an old item of information is either overwritten or incorporated into a record and transferred to LTM. Whether or not an old item of information is incorporated into a record depends upon its relevance to the overall experience. The relevance of a specific item to other items in the input information is determined by the parser which integrates information into higher level structures; it sets the goal under which event items are embedded, and it also pulls event items together to integrate them under a single node or into chunks of temporal units (e.g. causal-enabling links). Thus, if the parser establishes the goal of the 'Smarties event' such that less (or no) emphasis is placed on the t(S) representation, this t(S) representation will not be integrated into a record and will subsequently be lost when capacity is exceeded. This would be independent of marking; that is, even if the t(S) representation includes source information it may still be overwritten if it does not appear relevant to the goal.

My assumption is that the first question - 'what do you think is in this tube?' - initially sets up a goal of finding out about the contents of the tube. Subsequent information will then be organised in relation to this initial goal. Thus, the tube is first represented as containing Smarties. However, as soon as the Smarties tube is opened to reveal its true contents, the previous t(S) representation is no longer relevant to the goal that was initially established by the question. The emphasis is on initially, because the t(S) representation is still relevant to the overall current experience, but this will only become apparent when the test questions are asked. Therefore, if capacity is exceeded prior to the test phase, then when the parser integrates the Smarties event into higher level structures it will not include the t(S) information because it is, at this point, irrelevant. Unless the child has the capacity to hold both items of information until that point in time when the 'think' question is asked (and the t(S) representation becomes relevant), the t(S) representation is most likely to be lost; even if it is marked. However, if the t(S) representation was not marked, and then even if there is sufficient capacity to allow the t(S) representation to be maintained in the on-line buffer, it is likely to be updated (replaced) by the new t(p) representation, because this latter representation is more recent and more consistent with the goal.

When the 'think' test question finally arrives, the (episodic) t(S) representation no longer exists. The only content representation that is still available (the t(p) representation) is then used as a default answer. In principle, children could provide a correct answer if they were able to reconstruct their thought process, i.e. 'if I had not seen the pencil I would have thought
it contained Smarties because it usually does'. However, if the child does not have the ability to maintain the crucial items of information until the test questions are asked, it is unlikely that she will be able to make a complex inference (that requires the capacity to hold, at least, two arguments and a conclusion), even if the inference process or SP are fully competent. However, regardless of whether it is the competence of the inference process or capacity that restricts this process's performance, young children clearly do not use the inference route; they simply default to the only contents representation that is available to them - the t(p) representation. The fact that the evaluation process passes a wrong answer as correct may suggest that in the case when a complete match with the task specifications cannot be reached, a partial match is sufficient for positive evaluation.

To sum-up, I have identified 3 factors that could contribute to the failure of 3-year-olds on the Smarties task: capacity, relevance (as established by the parser) and marking. When capacity is exceeded, relevance determines whether or not the t(S) representation is encoded; marking determines whether the t(S) and the t(p) representations are in conflict. Both the marking ability as well as the capacity to maintain the representations until it becomes clear that both are relevant to the current experience are necessary for successful performance on a false belief task, but it is enough that only one of them is missing for failure to occur. In both cases, however, the failure will be due to loss rather than inaccessibility. Thus, 4-year-olds, who are successful on this task, can both maintain the representations and differentiate between them. In contrast, 3-year-olds may either not have the capacity, or not have the marking ability or both. I assume the last.

If the source of the difficulty in the Smarties task is associated with loss, then the task must be modified such that the initial t(S) representation is forced into availability by ensuring its consolidation in a record prior to the arrival of the conflicting information (i.e. the t(p) representation). First, the t(S) representation must be kept relevant until a record is created. Second, since I assume that the dispatching of records is triggered by changes within the event (such as changes in location or completion of sequences - see Chapter 4), a change must be introduced that will trigger closure. The 'Smarties-Bag' (SB) task was designed to meet both requirements.
6.4 'Pulling Smarties out of a Bag' - Introduction

As with the original Smarties task, the child is presented with a Smarties tube and asked "what do you think is in the tube?". Once the 'Smarties' response is returned, a bag is taken out of a drawer and the contents of the tube are emptied into the bag. During transfer the contents remain invisible. As soon as the transfer operation is completed, the child is allowed to have a look inside the tube. Then, the lid is put back on the tube and a question asked: "what is inside the tube now?" After the child answers this question, the tube is placed out of sight. The child is then asked "what do you think is inside the bag?". Once the 'Smarties' response is given, the bag is opened and the true contents of the bag, which is marbles, is revealed. The marbles are then returned to the bag and the child is asked the reality and think questions about both the bag and the tube. The same event, using different contents (a pencil rather than marbles), was repeated a week later.

The aim, as I have already said, was to create an event record from the information concerning the Smarties tube. Transferring the contents of the tube to the bag should maintain the relevance of t(S) representation, and putting the tube away should signal the completion of a mini-event which would trigger the creation of a record about the tube before the corrective information (marbles) arrives and makes the t(S) representation irrelevant. This record, which would contain the t(S) representation, could later be addressed and used at test. It was predicted that the t(S) representation will also be used correctly because even if it does not include source information, it could still be differentiated from the t(p) representation in relation to a time dimension - t(S) as the past model which resides in a record in LTM, and t(p) as the present model which resides in the on-line buffer. This, I hoped would help the children remember their Smarties response and lead them to provide the correct answer to the 'think' question.

The success of the 'posting' paradigm (Freeman & Lacohee, 1995; Mitchell & Lachoe, 1991) could be explained along similar lines. The posting of the picture of Smarties maintains the relevance of the t(S) representation before the corrective information can overwrite it, and the completion of the posting sequence triggers the closure of a 'posting' record that could potentially contain this representation. However, the difference here is that, unlike the transfer event, the posting event is independent of the tube and its real or believed contents. Therefore, the relationship between the t(S) representation and those components that make up the posting event would determine whether or not this representation is integrated within this
record. In other words, the t(S) representation may or may not be relevant to the posting event, although it is still relevant to the tube event. The difference between the relevant object and the relevant picture condition is that in the former the t(S) representation is not relevant.

This is because the Smarties that are being posted are necessarily independent of those Smarties that are believed to be in the tube - they are different Smarties, whereas the Smarties in the picture are not necessarily independent of the Smarties that are in the tube. In the relevant object condition, the best possible scenario is one in which the t(S) representation was dispatched as a record (when the posted objects entered the scene) but was subsequently blocked by the posting record or the actual reality. On the other hand, in the relevant picture condition, the t(S) representation could be included as part of the record associated with the posting and could later be addressed and used at test. Thus, rather than making an inaccessible t(S) representation accessible, the posting sequence made an unavailable representation available in one condition and inaccessible in the other.

The transfer sequence in the SB task is hypothesized to force the creation of a record that will contain the t(S) representation. It is therefore predicted that when children are asked about the tube they will be able to remember what they had thought by retrieving this record. This however, would be true only for the Tube condition. The Bag condition is predicted to produce the same level of failure as the original Smarties task since the computational demands in this condition are similar: as soon as the child express her belief, the corrective information overwrites it. Still, at the end of this event children would be expected to have created a record of the bag sub-event as well as of the tube. These records could potentially provide children with a structure that would help them anticipate and interpret a similar event, if one was encountered. For example, they would know that they would be asked questions about the procedure, and thus, the goal of the event may be set differently on a second presentation, such that the relevance of the t(S) representation is maintained. The knowledge that two different questions were asked in the first event (‘think’ and ‘reality’) would have made them aware of some duality (even if they could not resolve it the first time), therefore, when they are asked the belief establishing question on a subsequent occasion they would be more likely to include source information in their belief representations. If these assumptions are correct, then repetition of the SB event should significantly increase success rates in the Bag condition as well as lead to a further improvement in the Tube condition.
6.5 Method

6.5.1 Design

The following is a within subjects design. The task (SB) was a variation on Perner Leekam and Wimmer's (1986) Smarties task, but unlike the original, instead of revealing the tube's content immediately after establishing the child's beliefs about it, the tube content was first transferred to a bag, a belief about the bag's content established and only then was the true content revealed. A test question addressing knowledge of the initial belief, and a control question confirming knowledge of current reality, were then presented. A belief/reality pair was given first for the bag and then for the tube. This order of questioning was fixed for all children. The bag-then-tube order was to ensure that the computational demands in the Bag condition were similar to those of the original 'Smarties' task.

The same procedure was carried out a week later. On the 2nd presentation the marbles were replaced by a pencil.

The independent variables were:
1. Computational complexity - varying between Bag (difficult) and Tube (easy) conditions.
2. Number of exposures to the event - one vs two exposures.

The dependent variable was a categorical measure of 'correct' or 'incorrect'. In order for a response to be categorized as a 'correct' the child had to provide a correct response to both the belief and reality questions.

6.5.2 Subjects

Twenty four nursery school children (12 boys and 12 girls) aged between 3:0 and 4:6 (mean age 3:11) were tested. Half the children were over 4 years old and half under 4-years-old. Within each of these age groups there were equal numbers of girls and boys. The children were drawn from two different nurseries, one state-financed and one private, and were of varying socio-economic backgrounds.

6.5.3 Materials

The materials used for this experiment consisted of a tube of Smarties (Smarties are a sweet highly familiar to British children), a small soft-leather bag, 3 blue marbles, and a pencil. An audiotape was used to record and transcribe the procedure.
6.5.4 Procedure

Prior to testing, I spent a couple of hours in each nursery talking and playing with the children in order to establish a certain degree of familiarity. Children were then tested individually in a screened-off area of the nursery. Each child was presented with a Smarties tube and asked what they thought was inside the tube. The expected 'Smarties' response, based on the child's previous encounters with similar tubes, was assumed to establish an initial belief representation of the tube as containing Smarties which, in the context of the experiment, would turn out to be false. Once the 'Smarties' response had been provided, a bag was brought into sight and the content of the tube was emptied into the bag. During the transfer operation the content remained invisible. As soon as the transfer had been completed the child was allowed to have a look inside the tube. The lid was then put back on and a question addressing knowledge of the present state of the tube (emptiness) was asked. The reality-confirmation question ("what is inside the tube now?") was included to ensure that the children were fully aware that whatever was inside the tube was no longer there. This was to eliminate the possibility that children resolved the 'think-reality' conflict by representing the tube as containing both Smarties and marbles. Following the reply, the tube was placed out of sight and the child was then asked what s/he thought was inside the bag. Once the 'Smarties' response was given the bag was opened and the true content of the bag (marbles) was revealed. The children were encouraged to name the object(s). In cases where the word 'marbles' appeared to be unfamiliar (i.e. the child would not produce it spontaneously or as a repetition) the term 'blue balls' was offered as an alternative. The marbles were then returned to the bag and the child was asked the following questions:

1) THINK: "Before I opened the bag, what did you think was in the bag?"
2) REALITY: "What is really in the bag?"

The bag was then put away. The tube was then taken out again and the test questions concerning the tube's different states were asked. Two possible reality questions were relevant in this condition and both were asked:

1) THINK: "When I first showed you the tube, what did you think was inside the tube?"
2) PRESENT REALITY: "What is inside the tube now?"
3) PAST REALITY: "What was really in the tube?"

The same procedure was repeated a week later, this time using a pencil instead of marbles. In this 2nd event both a 'Smarties' and a 'marbles' response to the belief-establishing questions ("what do you think is inside the tube/bag?") were accepted as legitimate beliefs.
6.6 Results

Since the main focus of this study is the young child's general processing abilities rather than their ToM competence, all possible responses were accepted as valid expressions of the system's behaviour. The children's responses were categorised as either 'correct' or 'incorrect'. In order for a response to be categorized as 'correct' the child had to provide a correct answer to both the belief (Smarties) and the reality (marbles) questions. Any other pattern of response was categorised as incorrect. The patterns of response within the 'incorrect' category will be discussed at a later point. The response category in the Tube condition were the same except that in this condition children had to answer all 3 questions correctly in order to be given a 'correct' designation.

In the 2nd event both marbles and Smarties were accepted as valid beliefs (i.e. as appropriate answers to the initial question "what do you think is inside this tube?"). Therefore, a child's 'think' response at test had to correspond to her original belief - whether that original belief was Smarties or whether it was marbles. In the 2nd event, 13 out of the 24 children believed that there were marbles in the tube.

An initial inspection of the data revealed no effect of age. The older group demonstrated the same level of success that would normally be expected of younger children. The most likely explanation for this is a differences in socio-economic backgrounds as most 4-year-olds were from the state financed nursery, whereas the majority of the younger children were from the private nursery. Thus, the two age groups were collapsed, and the total scores across ages were entered for analysis. Table 6.1 presents the frequencies within each response category broken down by Event and Condition.

<table>
<thead>
<tr>
<th></th>
<th>1st Event</th>
<th>2nd Event</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Bag</td>
<td>Tube</td>
</tr>
<tr>
<td>Correct</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Incorrect</td>
<td>16</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 6.1

*Frequencies of correct/incorrect responses as a function of Event and Condition.*

N = 24
The improvement in performance that was predicted for the Tube condition is clearly evident in Table 6.1. Children answered correctly the questions concerning the tube more often than they did the questions concerning the bag. The increase in the number of correct responses from the Bag condition to the Tube condition was significant in the 1st (McNemar, binomial N=9, k=1 p < 0.05 - Bag1 (8/24) vs Tube1 (15/24)), but not in the 2nd event. The non-significant Condition effect in the 2nd event is almost certainly attributable to the already high level of performance in the Bag condition in this event. Also in line with the predictions was the observed increase in the number of correct responses in the Bag condition between events. Performance in the Bag condition in the 2nd event (Bag) was significantly better than performance on the Bag condition in the 1st event (Bag1) (McNemar, binomial N=9, k=0 p < 0.01 - Bag (17/24) vs Bag1 (8/24)). The differences between the Tube1 and Tube2 conditions did not reach significance.

6.6.1 - Response Patterns Within the Incorrect Category

Within the 'incorrect' category, 50% of children exhibited a response pattern that has not usually been reported in the literature. This pattern was characterised by a reversal between the 'think' and the 'reality' responses. Children exhibiting this pattern returned a 'think' response (Smarties) to the 'reality' question and a 'reality' response (marbles) to the 'think' question. In the published literature (e.g. Freeman & Lacohee, 1995; Gopnik & Astington, 1988) this 'reversed' pattern of response is universally excluded from analysis since failure on the reality question (or the 'control' question, as it is referred to in these studies) disqualifies the child from further participation. The justification for the exclusion is based on the view that nothing can be concluded about their understanding of beliefs if children are confused about reality. In my view however, apparent confusion about reality (a 'reversed' response) is no less intriguing than confusion about beliefs as both reflect the workings of the system. In addition, the question of primary concern in this study was whether or not the original belief representation (Smarties) can be made available for access. The 'reversed' response pattern was therefore of interest, because it indicates the availability of the belief representation even as it demonstrates inappropriate access.

Consequently, the children's responses were assigned to one of three categories: correct, reversed and double. The last category included children who made the usual mistake of providing the 'reality' (marbles) answer to both the 'reality' and 'think' question. In addition,
it included one child who replied with a 'think' (Smarties) response to both questions. In the Tube condition, children were required to provide a correct 'think' response and two correct 'reality' (marbles, nothing) answers, in order to be classified as 'correct'. A 'reversed' response indicated a reversal between 'think' and one of the 'reality' answers (e.g. marbles, nothing, Smarties; or nothing, nothing, Smarties - the order corresponding to the order of questions). Finally, children who gave one of the 'reality' responses in reply to the 'think' question (e.g. marbles, nothing, marbles; or marbles, nothing, nothing) were classified as double. This category also included a child who used the 'think' response as an answer to all three questions (Smarties, Smarties, Smarties). Table 6.2 shows the frequencies within each response category as a function condition (Bag/Tube) and number of exposures to the event.

### Table 6.2

<table>
<thead>
<tr>
<th></th>
<th>1st Event</th>
<th>2nd Event</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Bag</td>
<td>Tube</td>
</tr>
<tr>
<td>Correct</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Reversed</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Double</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

**Scoring**

The new response categories were ordered on an ordinal scale of correctness, with the 'reversed' pattern classified as being an intermediate stage between pass ('correct') and fail ('double'). The different response categories were each given a value to yield scores of 0, 1 or 2 per subject per condition, each subject thus providing 4 scores in total. The scores corresponded to a degree of 'correctness' and were determined by a trade off between the availability of the representations and an appropriate assignment of belief. A 'correct' response, which demonstrated both availability and proper assignment of belief, was given a value of 2. The intermediate, 'reversed', response was given a value of 1, as it indicated availability of the
belief representation but inappropriate assignment of belief. A 'double' suggested neither availability nor appropriate assignment of belief and was therefore scored as 0. Table 6.3 shows the mean and standard deviation of 'correctness' for each condition in each event.

<table>
<thead>
<tr>
<th></th>
<th>1st Event</th>
<th>2nd Event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bag</td>
<td>Tube</td>
</tr>
<tr>
<td>mean</td>
<td>1.00</td>
<td>1.37</td>
</tr>
<tr>
<td>sd</td>
<td>0.83</td>
<td>0.87</td>
</tr>
</tbody>
</table>

A Condition (Bag vs Tube) * Event (1st event vs 2nd event) analysis of variance with repeated measures on both factors was conducted on children's scores. The analysis revealed significant main effects for Condition \( F(1,23) = 6.76, p < 0.02 \), and for Event \( F(1,23) = 9.57, p < 0.01 \), with no significant interaction. A matched samples t-test was used to analyse the differences between specific conditions. The increase in degree of correctness from the 1st to the 2nd event was significant for both the Tube and Bag conditions. Children's performance in the Bag condition in the 2nd event (Bag2) was significantly better than their performance in the Bag condition in the 1st event \( t(23)=3.25, p < 0.005 \). There was also a significant improvement in performance in between the Tube2 and Tube1 conditions \( t(23)=1.82, p < 0.05,1\text{-tail} \). The fact that this comparison was significant, whereas the equivalent comparison in the McNemar was not, is presumably because of the greater discrimination afforded by the

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15 This scoring orders children on an ordinal scale of correctness, which does not necessarily assume fixed 'improvement' intervals between the different response. However, given that the principle theoretical concern is with the existence, or availability, of the representation of the original belief, the main objective of this design was to help children cross the threshold between availability and non-availability of the belief representation. From this theoretical point of view, then, the increase (in terms of units of correctness) from 'double' to 'reversed' would be larger than the increase from 'reversed' to 'correct'. This, however, would only bias an analysis of 'correctness' in the opposite direction, in that the relative contribution of the 'reversed' category to the derived means would be less than the theory would otherwise predict. Therefore, it is less likely to lead to type I error.

16 For a discussion on the robustness of the ANOVA for violation of the normality assumption see Box (1953), Boneau (1960) or Bradley (1964).
ordinal scoring system. The differences in levels of performance in the Condition factor was significant only within the 1st event. Children performed significantly better in the Tube1 condition than they did in the Bag1 condition (t(23)=2.09, p < 0.025). As with the McNemar test, the difference between the Tube2 and the Bag2 conditions was not significant, possibly as a result of a ceiling effect in the Bag2 condition.

6.6.2 Qualitative analysis

The statistical analysis revealed significant changes in the level of 'correct' performance between the experimental conditions, but it obscured much of the information about the dynamics of this change. For example, were any children consistent within a particular response type? Did a given child show a steady improvement in her performance from one condition to the next? In Figure 6.2 an attempt is made to capture the quality of these changes.

![Figure 6.2](image)

The four horizontal sections in the tree structure correspond to the four experimental conditions. Each branch in the tree structure corresponds to an observed pattern of change within a given subject. The numbers in each section of a single branch indicate the number of children in which that particular pattern was observed. The tree structure consists of three main branches (correct, reversed, double) corresponding to children's initial responses in the Bag1 condition. I will first discuss the patterns of change within each of these groups and then the overall dynamics of change within conditions.
Patterns of change within (initial response) groups

First, children who were classified as correct in Bag1 were, on the whole, likely to be consistent with this pattern of responding.

Second, children whose initial responses were a 'double' did not maintain this pattern across all the experimental conditions. All but one of these children gave a correct response on at least one experimental condition (and even this one child had the belief representation available at least as a 'reversed' pattern of response). Overall, by the 2nd event (Tube2 in particular), the majority of children within this group improved their level of performance.

Third, as with the 'double' category, all except one child within the initial 'reversed' category provided a 'correct' response on at least one of the conditions (and the child who did not, still had the belief representation available as a 'reversed' response). Unlike the previous group, however, improvement in the 'reversed' group was not as consistent. A few instances of regression in performance were evident (i.e., C->R or R->D) in this group.

The overall pattern of change within condition

Three of the matched t-test comparisons were found to be significant: Bag1 vs Tube1, Bag1 vs Bag2 and Tube1 vs Tube2. Figure 6.2 reveals certain trends that may point to the underlying factors contributing to these improvements. I will now focus on the changes from 'reversed' and 'double' to 'correct' responses across all subjects.

The increase in the number of 'correct' responses within the Condition (Bag/Tube) factor seems to be attributable mainly to changes from 'reversed' responses to 'correct' responses. Seventy-five percent (6 of 8) of children who provided a 'reversed' response in the Bag1 condition were 'correct' on the Tube1 condition, in comparison with a 25% (2 of 8) improvement in the 'double' response group. This difference in performance was significant ($X^2 = 4.00, df = 1, p < 0.05$). The same pattern of change is evident between the Tube and Bag conditions in the 2nd event: 75% (3 of 4) of children whose response to Bag2 was 'reversed' changed to 'correct' in Tube2, whereas only 33% (1 of 3) of the children who produced a 'double' response demonstrated such improvement. The $X^2$ in this case was not significant, but this is almost certainly attributable to the low power of the test as the sample size is very small. Thus, the reduction in computational demands that was afforded by the transfer operation seems to have been less effective for those children who, for reasons that I will discuss shortly, produced the 'double' pattern of response in the Bag1 condition.
In contrast, the improvement in the Event factor seems to be equally distributed between the 'reversed' and 'double' responses. Inspection of the changes from Bag1 to Bag2 reveals that 50% (4 of 8) of the children who provide a 'reversed' response in the Bag1 condition changed to 'correct' in the Bag2 condition; similarly 62% (5 of 8) of the 'double' responses in Bag1 changed to 'correct' responses in Bag2. The changes between Tube1 and Tube2 are similar in that the improvement is equally distributed between the two wrong categories, however, the level of increase within the Tube condition is higher than the increase within the Bag condition. There was a 67% (2 of 3) increase from reversed to 'correct' and an 83% (5 of 6) increase from 'double' to 'correct'. This is to be expected since the Tube2 condition is the only condition in which both independent variables (processing complexity and repetition) are at play. This condition enjoys both a reduction in computational complexity (in comparison to the Bag condition) and the advantages of having a record of the previous experience to aid interpretation of the current experience.

Thus, while the reduction in computational demands was less affective for the 'double' group, repetition of the event was of benefit to both. This and the differences between the 'double' and 'reversed' groups that I have noted above (i.e. consistent improvement for the 'double's vs inconsistent improvement for the 'reversed') may suggest that the developmental profiles of the groups are different.

6.7 Discussion

The results from the SB study clearly supported the predictions. There was a marked improvement from the Bag condition to the Tube condition in the 1st event, as well as an improvement between the 1st and 2nd events. In the 1st event, children were better able to answer correctly the questions concerning the tube (63%) than those concerning the bag (33%), with the level of success in the latter condition (33%) being similar in magnitude to the levels of success that have been commonly reported for the original Smarties task. Performance on the Bag condition, however, was much improved by the 2nd event. On the second presentation 75% of the children were able to answer correctly the questions concerning the bag, and there was also an additional small improvement in the Tube condition in this event.

In the introduction I identified 3 factors that could contribute to the 3-year-old's failure on the original Smarties task: capacity, relevance and marking. I argued that the ability
to provide a correct answer in the original task depends on the child having both the capacity to maintain the crucial t(S) representation in the on-line buffer until it becomes clear that it is relevant (otherwise it will be passively overwritten when capacity is exceeded), and on the ability to differentiate between the belief [t(S)] and the reality [t(\text{marbles})-t(m)] representations along some dimension (or the less recent t(S) representation will be actively replaced). I assumed that making an event of the Smarties response would keep this t(S) representation relevant to the experience long enough for it to be dispatched to LTM before the arrival of the conflicting piece of information. The transfer operation was introduced to achieve this goal. Transferring the contents of the tube into a bag was to maintain the t(S) representation relevant in the context of the tube; putting the tube away was to signal the completion of an event sequence, and trigger the creation of a record containing information regarding the tube which would include the t(S) representation. In this way, I aimed to solve the problem of loss - either due to passive overwrite or active replacement - and ensure availability. In addition, since at the time of test the t(S) representation is in a record and the t(m) representation is in the on-line buffer, these representations, which would be unmarked in the 1st event, could be potentially differentiated in relation to a time dimension (past and present). Therefore it was predicted that the t(S) representation would be accessed correctly. In contrast, in the Bag condition, it was predicted that the same level of failure would be observed as in the original Smarties task, since the computational demands were similar: as soon as the bag is represented as containing Smarties [bag(S)-b(S)], the true contents of the bag (marbles) is revealed and the new b(m) representation replaces it.

Overall, the data supported these predictions. In the 1st event, the number of correct responses in the Tube condition was significantly higher than the number correct in the Bag condition, with the success rate in the latter condition being of the same magnitude as in the original Smarties task. However, the pattern of failure in the Bag condition was different. Unexpectedly, a third of the children in this condition produced a 'reversed' pattern of response. Children producing this type of response clearly have both belief and reality representations available to them, but they appear not to be able to distinguish between these representations. Furthermore, their behaviour also suggests that destructive update (replacement), which is expected to occur when the representations are indistinguishable, did not, in fact, occur.
One possible explanation is that the representations were distinguishable, but that confusion may have occurred at the input stage due to certain linguistic biases that lead to a wrong interpretation of the 'think' question. Thus, instead of understanding the 'think' question 'Before I opened the bag, what did you think was in the bag?' as an inquiry about their past thoughts concerning the bag, children may have understood the question as being about their present thoughts concerning the bag's past. Since there is no difference between the past and present state of the bag, the reality answer would be the correct answer. When the reality question is subsequently presented (and given that both representations are available) then, by virtue of being a different question, the reality question may lead the evaluation process to reject an identical answer and force a default output of the only other alternative - the false belief representation; alternatively, since there is no difference between the past and present state of the bag, the child will reply with the same answer as before - this time referring to the bag's present state. In the next Chapter, I will report a study which tested and rejected this hypothesis. Thus, if the questions are understood correctly, the only other reason for confusion is if the child has two contents representations that are unmarked and therefore indistinguishable at the structural level.

Thus, we know from their response pattern that the children in the 'reversed' group did not have the marking ability, but they did have the capacity to maintain both representations until both questions were asked, and although the representations were indistinguishable, they did not update their original b(S) representation. Their behaviour, therefore, seems to suggest that destructive update is not a necessary consequence of conflict, and in the case where children have the capacity to maintain both representations they may attempt to incorporate them both into their representation of the event. In contrast, those children who produced the 'double' pattern of response had neither the marking ability nor the capacity.

Given that the main contribution to the increase in the number correct in the Tube1 condition was from the 'reversed' group, it can be concluded that the reduction in processing complexity that was afforded by the transfer operation was not sufficient for those children in whom both limiting factors were at play. Specifically, children with a more limited capacity seem to have had greater difficulties organising the event such that the correct (tube) responses could be accessed. This is not at all surprising given that capacity, as defined in Chapter 4, varies with the parser's fixed speed of processing. Since fixed speed of processing is
determined by knowledge of event grammar (or algorithmic knowledge) it is quite possible that the segmentation rules in a less developed parser could lead to the creation of inaccessible records. For example, if more, and consequently smaller records were created from the event, the probability of inaccessibility due to blocking would be greatly increased. However, as we already know from the 'Mickey' study, repetition of the event should rectify this situation since knowledge of event type (i.e. representational knowledge stored in records) can increase the relative speed of processing which in turn will increase record size and hence avoid the problem of blocking. This is in addition to the benefits of better comprehension of the global goal and awareness of a duality (of the think and the reality scenarios) associated with repetition, which I have already discussed.

The results from the 2nd event clearly demonstrated the benefits of repetition. On the 2nd presentation, a significantly larger number of children were able to provide correct responses to the questions concerning the bag. Since both the representations concerning the bag's contents are assumed to be still residing in the on-line buffer(s) and could not be differentiated on the basis of the past (contents of records) and present (contents of the on-line buffer), it can be concluded that those children who accessed these representations correctly could differentiate them at the structural level - i.e. through marking. In addition, only a small number of children, in both the Bag and Tube conditions, did not have the relevant representations available to them. It is particularly notable that only 2 of the 8 children that were initially classified as 'double' in Bag1 maintained this response in Bag2, and none of them repeated this response in the Tube2 condition. The improvement within these children in particular demonstrates the benefits of the previous experience with regard to the overall organisation of the event.

Similar general improvements were associated with the group of children who were initially classified as 'reversed' (in Bag1). However, within this group there were a few instances of regression. Since repetition of an event is assumed to increase the size and reduce the number of records, it may be that children with larger capacities who had initially represented the event in fewer records were able to integrate the information into a single structure on the second presentation, but then had difficulties at the output level as a result of the complexity of this structure. Furthermore, if children in this group did incorporate both the belief and reality representations into their record of the 1st event, despite the fact that those representation were unmarked and therefore in conflict, it is likely that this record, which is
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subsequently used to aid interpretation of the 2nd event, was less well organised and therefore potentially confusing. The number of children in which regression in performance was observed, however, is too small to draw any firm conclusions.

Overall, the results support the ToM performance approach and the hypothesis regarding limitations in children's processing skills, specifically with respect to capacity and on-line marking. Such results could not be obtained if the child had a representational problem with a false belief. If failure on the Smarties task is due to limitations in representational capacities that prevent children from understanding the differences between mental representations and reality, then a large number of 'double' responses would be expected across all conditions. Particularly, children whose initial response (Bag1) was a 'double' would be expected to maintain this pattern across all the experimental conditions. This however, was not the case (Figure 6.2). None of the children consistently provided this pattern of response. Overall, this particular design enabled children to maintain the representation of their original 'belief' response for subsequent access.

Proponents of the ToM competence approach may argue that in the Tube condition there is no problem of conflicting representations, and therefore there is no reason for children to fail the tube 'think' question. However, in order to answer the tube questions correctly, children not only have to access their belief representation but they also have to evaluate it and pass it as an appropriate response. It is at this stage of evaluation where a problem with understanding the concept of belief can lead to failure, because if there is a problem with the concept of belief, then the evaluation process will not be able to utilise the 'think' item in the task specification (i.e. the question) for evaluation purposes. Consequently, even if the t(S) representation is made available, there is still no reason for the evaluation process to pass this representation more often than any other tube representation that is available. The fact that children answered the tube questions correctly indicates that they were able to distinguish between the questions and correctly evaluate the answers to these questions; therefore they could not have had a problem with the concept of belief.

The improvement in the Bag condition from the 1st to the 2nd event presents even greater difficulties for the ToM competence explanation, because it demonstrates a single trial learning in a situation that presents children with the same representational change problem as the original Smarties task. Whatever the causal factor that makes it impossible to accommodate a 'thought' representation in a representational change situation, such competence limitations
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could not be overcome after a single trial with no feedback. Nor can a problem solving strategy be acquired, particularly not in the absence feedback. In other words, the child as a copy theorist (Wellman, 1988) or a situation theorist (Perner, 1991) could not become a ToM theorist after a single exposure. Strategy learning would also be highly improbable because learning from the first experience without feedback requires some understanding of the experience as it occurs, or subsequent reflection and reorganisation. However, by definition, neither a copy theorist nor a situation theorist can understand a representational change situation as it occurs, nor can they represent the parts they do not understand i.e. the 'thought' representation. Understanding a representational change situation through reflection and reconstruction is even less plausible, because reconstructing and representing that which is unrepresentable is a logical impossibility. A previous experience, however, could help an already competent ToM to realise its true potential. It could help children become aware of a duality and, therefore, of the necessity to mark their representations as they do when they are engaged in pretend play.

6.8 'Pulling Smarties out of a Bag' - Introduction to Experiment 2 (SB2)

In this section I will report a study that was designed with the aim of eliminating the 'reversed' pattern of response. The 'reversed' pattern of response, as already noted, indicates that the child has two contents representations which are unmarked and therefore indistinguishable. To reiterate, two contents representations are formed in the context of the task as it unfolds over time; one regarding the belief about the contents of the bag \[b(s)\], and the other regarding the observed contents of the bag, i.e. \(b(m)\). The representations represent the same relationship (i.e. containment) between one and the same container and two different objects. If the represented relationships between the container and the two objects are to be differentiated, it is either the case that the more recent representation \[b(m)\] receives a current state marker, or each representation receives a source marker (e.g. knowledge vs perceptual) at the time it is formed. If no marking procedure is carried out, the representations will remain identical on all but the 'object' dimension. Thus, those children who produce the 'reversed' pattern of response have two representations of a single container that are not differentiated on any meaningful dimension (i.e. time or source).

In addition, the 'reversed' pattern of response also appears to suggest that in the case where a question is asked, and there are two seemingly identical representations competing in
term of appropriateness, the more recent of the two would be addressed. Since the 'think' question in the previous SB design was first, the answer to this question was wrong because the more recent representation was the reality representation. The second, 'reality' question would then address (again wrongly) the alternative contents representation. Thus, if the order of the questions was to be switched, the 'reversed' pattern should be eliminated in favour of the 'correct' pattern.

I have mentioned earlier that in the theory of mind literature this pattern of response is rarely reported, and when it is reported the children that have produced it are typically excluded from analysis. Having established my explanation for the high frequency of 'reversed' responses in the previous SB task (which I will now refer to as SB1), I re-examined the methodology used in several of these studies. I found that in most studies the 'reality' (control) question was asked first (e.g. Perner, Leekam and Wimmer, 1987; Sullivan and Winner, 1991) and there were no reports of failure on the control question (i.e. a potential 'reversed'); Gopnik and Astington (1988) asked the 'think' question first, but reported no failure on the control question.

Freeman and Lacohee (1995) also asked the 'think' question first, however, unlike Gopnik and Astington, in four of the six experiments they reported the level of failure on the control 'reality' question was quite high (12%, 8%, 17% and 16%). In the remaining two experiments the level of failure was low (1% and 3%), but in these experiments the authors included an additional think/pretend question immediately after the standard 'think' question. This additional question appeared to have confused the children, as in both studies about 50% of children refused to answer it. The additional question and/or the confusion that it generated are likely to have eliminated the 'reversed' pattern of response, because under these conditions it is likely that the belief representation is lost before it has a chance to be used as an answer to the 'reality' question, when this question finally arrives.

Thus, if the recency assumption is correct and the first question addresses the most recent of two seemingly identical, and therefore competing, representations, then if the 'reality' question is presented first, the answer to this question should be correct since the most recent representation is the reality representation. The answer to the 'think' question should also be correct since a second (and different) question should address the alternative contents representation - the 'think' representation. It is therefore predicted that switching the order of
the ‘think’ and ‘reality’ questions in the SB design will eliminate the ‘reversed’ pattern of response in favour of the ‘correct’ pattern.

This second SB (SB2) experiment is also expected to replicate the positive effect that the reduction in computational complexity (afforded by the transfer operation) had on children’s performance in the Tube1 condition in SB1. Therefore, the children’s level of performance in the Tube condition in SB2 is expected to be of a similar magnitude as that observed in the Tube1 condition (i.e. the 1st event) in SB1. However, unlike the previous experiment, no difference between the Bag and Tube condition is expected in this study, because performance in the Bag condition should now be better. In fact, since most of the contribution to the number of ‘correct’ responses in the Tube1 condition in SB1 was from the ‘reversed’ group, and since the ‘reversed’ responses are now predicted to change to ‘correct’s, performance in the Bag and Tube conditions should be similar in this study.

6.9 Method
6.9.1 Subjects
Twenty four nursery school children (12 boys and 12 girls) aged between 3:0 to 4:6 (mean age 4:0) took part in this study. Half the children were over 4 years old and half under 4. Within each of these age groups there were equal numbers of girls and boys. The children were from two state-financed nurseries and were of varying socio-economic backgrounds.

6.9.2 Design and Procedure
The design and procedure were the same as in the previous study (SB1), except that the order of questions was different. In this study the ‘reality’ question was always asked first.
Bag condition:
1) REALITY: “What is really in the bag?”
2) THINK: “Before I opened the bag, what did you think was in the bag?”

Tube condition:
1) PRESENT REALITY: “What is inside the tube now?”
2) THINK: “When I first showed you the tube, what did you think was inside the tube?”
3) PAST REALITY: “What was really in the tube?”
There was also no repetition of the event.
6.10 Results and Discussion

Children were classified into 3 response categories, using the same classification criteria employed in the previous study. Table 6.3 presents the frequencies within each response category in the Tube and Bag conditions that were observed in SB2 and those observed in the 1st event in SB1. The table therefore includes data from 48 subjects, 24 in each of the two studies.

Table 6.4

*Frequencies within each response category in the SB2 study and in the 1st event in the SB1*

<table>
<thead>
<tr>
<th></th>
<th>SB2</th>
<th>SB1 - 1st event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bag</td>
<td>Tube</td>
</tr>
<tr>
<td>Correct</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Reversed</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Double</td>
<td>14</td>
<td>8</td>
</tr>
</tbody>
</table>

Inspection of the data reveals almost identical patterns of response in the Tube conditions in each study, and quite large differences in the patterns of response between the Bag conditions in each study, in particular with respect to the ‘reversed’ and ‘double’ patterns of response. As predicted, the number of correct responses in the tube condition was the same in both studies. Thus, the effect of reduction of computational complexity on performance in the Tube condition was replicated. Also in line with the predictions, the frequency of the ‘reversed’ pattern of response was greatly reduced. However, contrary to the prediction, the reduction in the number of ‘reversed’ responses did not shift the balance in favour of the correct pattern, which maintained a similar frequency of occurrence as that observed in SB1. Instead, there was a significant shift in favour of the ‘double’ pattern of response ($X^2 = 5.11$, df = 2, $p < 0.05$). This shift towards the ‘double’ pattern of response seems to rule out the recency explanation as the solution to the problem of competition between two seemingly identical representations. Alternatively, it may suggest that in this situation there was no competition to evoke the recency principle. I will argue the latter.
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Two conclusions can be drawn on the basis of the results from the SB experiments. First, the identical levels of success on the Tube conditions in both studies, in conjunction with the finding that the improvement in the Tube condition in SB1 was significantly associated with changes from 'reversed' responses to 'correct' responses, suggest that a similar proportion of children in this study had the same developmental profile as those children who produced the 'reversed' pattern of response in SB1 - i.e. children who have the capacity to maintain both representations but lack the marking ability.

Second, this group of children (who I will continue to refer to as the 'reversed' group) in SB2, did not have the belief representation [i.e. b(S)] available to them at the time the second ('think') question was asked, although it must have been available at the time the first ('reality') question was asked, since the experimental conditions up to that point were the same as in the previous SB study. It seems reasonable to conclude then, that the 'reality' question caused the loss of the b(S) representation in this group, otherwise they would have used it as they did in the previous experiment. This in turn suggests first that there is something different about the 'think' and 'reality' questions that helped to maintain the belief representation in one case and led to its loss in the other, and second that children know that there is a difference and respond to it.

One difference between the 'think' and 'reality' questions is the effect each would have on the perceived goal, and consequently on the relevance of the belief representation to this goal. The reality question reinforces the original goal of finding out about the content of the bag, which renders the b(S) representation irrelevant. In contrast, the 'think' question is likely to change or expand the goal and therefore maintain the relevance of the b(S) representation. But, if the representations are indistinguishable, this effect should not in principle be expressed; that is, if both representations are available and indistinguishable they both should pass as appropriate answers to either the 'think' or the 'reality' question. However, the SB1 experiment seems to indicate that this was not the case. Once the reality representation was provided as an answer to the 'reality' question, the belief representation was lost, which suggests that the response in this case was selective, and that it motivated updating of the belief representation; but then, this would necessarily mean that the representations are distinguishable. However, we know from the SB1 study that the representations were indistinguishable at the structural level, or else the children who had both representations available would have produced a 'correct' pattern of response. The only solution that would
allow the representations to be distinguished in relation to reality - but not in relation to 'thought' - is one that assumes that there is something special about 'reality' representations, not in terms of their structure but in terms of their location.

A similar solution was proposed as a way of resolving the problem of differentiating between unmarked representations in the Tube condition. The belief and reality representations associated with the tube are also unmarked and structurally similar, however, they can be distinguished in terms of their location in the system - the belief representation in a record in LTM, and the reality representation in the on-line buffer. The belief and reality representations associated with the bag could be distinguished along similar lines if it is assumed that they each reside in different on-line buffers, and if one of these buffers imposes itself as reality. Thus, reality will be associated with one specific buffer, whereas 'think' could in principle be associated with both. In the next chapter I will postulate an additional on-line buffer for the temporary storage of interpreted or retrieved information, in which the belief representation resides from the start. The original buffer I will then re-specify as a current state buffer storing post attentional perceptual information which imposes itself as reality.
7. THE TRUCK EXPERIMENT

7.1 An Overview

The following experiment was originally designed to explore a linguistic explanation for children's failure on the SB task and on the original Smarties task. The critical question was whether children's failure on these tasks is caused by a particular linguistic bias that prejudices their interpretation of the 'think' question and leads them to produce incorrect patterns of response. In brief, the child may interpret the question "Before I opened the bag, what did you think was inside the bag?" either correctly, as referring to the child's past thoughts about the container, or incorrectly, as referring to the container's past state. Antinucci and Miller (1975) and Bronckart and Sinclair's (1973) proposal that the early use of past tense is object centred rather than actor centred would suggest that children may be biased towards the incorrect interpretation.

The truck experiment was designed to investigate a similar bias in comprehension by manipulating the tense used in questions interrogating memory of a non-mental-state event. This linguistic alternative was subsequently ruled out as a viable explanation. Children's patterns of response showed no indication of difficulty with comprehension of the past tense. Provision of correct responses was independent of the time-reference paraphrase used in a question. Instead, responses were found to depend on the order in which the questions were asked, with different order configurations leading to destruction of different items of event information. For reasons that will become clear in the discussion, these data led to the inclusion of an additional on-line buffer in the model.

7.2 General Background

Investigating linguistic biases and the limitations these may exert on performance on the Smarties tasks was motivated by the data obtained in the SB1 experiment. Recall that the SB task was designed to reduce capacity demands placed on children, and in this way increase
their success rate on a false belief task. The design achieved its overall objectives, but it also produced a pattern of response that has not been previously reported in the literature - the 'reversed' pattern. It was this novel pattern that drew attention to the linguistic component of tasks such as the SB and the Smarties, and to the potential contribution of a linguistic factor to performance on these tasks. The 'reversed' pattern may reflect a difficulty children have with the comprehension of auxiliary questions. The standard test question 'Before I opened the bag/tube what did you think was inside it?' contains two past auxiliaries, one associated with the act of thinking and the other with the bag's contents. The way the question is interpreted would depend on the auxiliary that is given more weight. If the auxiliary 'did' is given more weight, then the question would be understood as an inquiry about the child's past thought concerning the container. If, however, the auxiliary 'was' is given more weight, then the question would be understood to be an inquire about the child's present thoughts concerning the past state of the bag.

When the auxiliary 'did' is focused on, as it should be, (What did you think with regard to the contents of the 'X', before the contents was revealed), the question addresses the child's past thoughts about the contents of a particular container. In order to answer correctly, children would be required to address a representation of their past belief state which differs from their present knowledge state. The common assumption, within the theory of mind domain, is that children do interpret the question 'correctly'. However, they fail the Smarties task because they have a conceptual difficulty with the belief construct. The data from the SB task have falsified this assumption. With reduced computational demands, more children were able to answer the questions correctly. The only condition in which no improvement in the number of correct responses was observed was the Bag1 condition which imposed the same computational demands on the system as the original Smarties task (see discussion in the previous chapter). However, in this condition half of the 'wrong' responses were from the 'reversed' category which demonstrates availability of the belief representation. Thus, if children understand the questions correctly then the only other reason for the observed 'reversed' response is the exclusion of markers from representations (see Chapter 6).

If, however, the second auxiliary receives more weight, the question would be understood as 'What (do you think) was the content of the bag, before the content was revealed'. When interpreted this way, the question enquires about the past state of the container. The child, making the correct assumption that there is no difference between the
past and present state of the bag, will simply address her representation of her present state of knowledge about the bag. Consequently, when the next, reality question is presented, either a 'double' or a 'reversed' response will be observed. First, since there is no difference between the past and present state of the bag, the child will reply with the same answer as before, this time referring to the bag's present state. This would produce the double pattern of response even if both belief and reality representations exist. Alternatively, by virtue of being a different question and given that two contents representations are available, the reality question leads to the evaluation process rejecting an identical answer and forcing a default retrieval of the only other alternative - the false belief representation. The literature provides some evidence in favour of this latter interpretation.

For example, looking at comprehension of Wh-questions, Stewart and Sinclair (1975) found that auxiliary inversions which disturbed the normal Subject-Verb-Object (SVO) order, led to incorrect answers even with children as old as nine. When an auxiliary disturbed the SVO order, children indicated the inverse situation to the one mentioned in the question. For example, when children were asked 'Which monkey did the bear knock over?' they pointed to the situation in which the monkey knocked over the bear rather than the bear knocking over the monkey. The authors have suggested that "the error may be due to linking the first noun (monkey) to did+V (knock over) as a subject; thus, it may be that the first N is wrongly decoded because it directly precedes an auxiliary" (p. 24, where V = verb; N = noun). This, however, only re-describes children's behaviour, it does not provide an insight into the mechanisms that may produce it. Unfortunately, there does not appear to be any other data on the comprehension of auxiliary questions that could shed more light on the matter. The existing data goes only so far as to suggest that children have difficulty with auxiliary questions, in which case the belief question in the SB and the Smarties tasks should be equally hard for them to decode linguistically. The problem remains as to what might influence the decoding of such questions?, which leads me to another set of data regarding object centred biases in children's production of past verb inflection.

If children make linking errors with Wh-auxiliary questions, then whatever biases they may have should lead them to make certain type of links more readily that others. Antinucci and Miller (1975) and Bronckart and Sinclair (1973) have both suggested that the early use of the past tense is object centred rather than actor centred. According to these authors, younger children generally use the past tense to describe the present condition of an existing
object, a condition that resulted from a past action, rather than to convey the pastness of an actor. If similar biases govern comprehension, then the auxiliary associated with the bag's state would be given more weight than the auxiliary associated with the act of thinking. For example, Antinucci and Miller's (1975) analysis of young children's protocols revealed that stative verbs (e.g. know) and activity verbs (e.g. dance) are not often used in their past tense form in the children's speech, although they do occur in the present tense, whereas change of state verbs (e.g. break) do occur in the past. 'Think' is a stative verb and thus would be expected to occur in the present, therefore, "what did you think" may be treated in the same way as "what do you think now about what was the case then".

Harner (1981) also reported that 3-year-olds used the present tense most frequently, and 40% of the time they used it to refer to past actions. However, she suggested that children used the present tense to describe past actions not because they cannot conceptualise actions as past, or because they do not know the linguistic forms to indicate the pastness of an action, but because younger children do not fully grasp that what is wanted is a description of the action as occurring either before or after their descriptive speech event. Thus, children would be more likely to understand the question as referring to the state of the container because they are more likely to understand (the act of) thinking to refer to their 'now' state of thought rather than to their 'before' (past) state.

It seems then, that in children, reference to the past is biased to some degree towards actions responsible for an object's states instead of actions associated with an actor's states. Thus, if the comprehension of questions is governed by object-centred biases, then children would be more likely to understand the pastness of the 'think' question to refer to the container's state in the past rather than to their own past thoughts about the container's unchanged state. The type of response returned (double vs reversed) and the pattern of improvement across conditions will then depend on whether the biases that led to the original misinterpretation are an expression of competence limitation regarding linguistic forms (i.e. one which will be associated with the 'double' pattern of response); or whether they are biases that reveal themselves in the face of complexity or ambiguity. In the latter case, the biases may be overcome if the ambiguity is resolved by the next question (leading to the 'reversed' pattern of response) or by the next condition, which may explain the improvement between conditions in the SB task. Generally, however, the truck experiment is less concerned with the underlying causes for such linguistic biases than with exploring the possibility of their existence in non-mental state situations that present children with similar linguistic complexity as the SB task.
7.3 Introduction

The main aim of the truck experiment was to investigate object-centred biases in comprehension of questions of the same linguistic complexity as those used in the bag task. Specifically, if children are presented with a question such that one part of the question refers to the actor's past and the other to the object's past, do they show a tendency to focus on the part of the question referring to the object? The transfer idea of the Bag design was borrowed to create an event that involved changes of state for both object and actor. This time, however, the situation did not involve a mental state component.

In addition to examining linguistic biases in comprehension, the truck experiment was designed to further explore children's memory for events. To this end the truck event was made more elaborate than was otherwise necessary to simply test for a linguistic bias. The transfer activities were embedded in a pretend game in which the child was actively involved. The event as a whole was designed to conform to general script characteristics, specifying a goal and consisting of a number of main acts, actors and props. Although the event unfolded over two locations, most activities occurred in a single location and with relative speed. The event was designed this way specifically to overload the child's limited capacity. Since there was no conflict between event items, no loss of information was expected to occur as a result of destructive update, nevertheless some information could still be potentially lost as a result of passive overwrite. In addition, some event items were expected to be provided as wrong responses to the test question if the hypothesised linguistic biases did exist.

The children participated in a pretend game about a family that was moving from one town to another. Children played the part of the truck driver who was to move objects between the old and new locations. Two trucks and 4 object types were used. Children had to carry truckA + object1 from Location1 to Location2, they then had to unload truckA and truckB + object2 which was standing loaded in Location2 and reload both trucks with two other contents (one for each truck). Thus, an initial and final contents were associated with each truck. Once both trucks were reloaded, children were to carry truckB + object4 from Location2 to Location1 (leaving truckA + object3 in Location2). On arrival in Location1, and before the children completed the full journey, they were asked 3 questions about the trucks' contents at different point in time:

(Q1). The truck that you carried what was in it?
- Correct Answer: Object1 - truckA's Initial State
The questions interrogate memory for the initial and final states of both trucks. The final state of truckB was not addressed as it was directly visible. The questions reflect the structure of the 'think' question in the bag task, containing two clauses, the first associated with the actor's act of 'carry' and the 2nd with the truck's state. The first question refers to the past state of the past truck, or in other words to the past state of the truck with which the child was involved in the past. Thus, it enquires about the child's past. The second question refers to the past state of the present truck, or the truck that features in the child's present. Answering these questions correctly would indicate that whatever linguistic biases children do have, they do not affect their comprehension of past-tense questions. The third question in this scenario serves as a memory control since it is expected to be answered correctly if the representation of truckA's final content was not lost due to overload. Thus, if linguistic biases do not play a role in the comprehension of questions, and if there is no loss due to overloading (child's capacity), then all three questions should be answered correctly.

From a memory perspective, the question enquiring about the initial state of truckA (Q2) should always be answered correctly since it is expected to have been encoded in a separate record with the change from Location1 to Location2. It has already been suggested in Chapter 4 that changes in location trigger record closure. Based on this assumption, the change from Location1 to Location2 should trigger the closure of a record in which information associated with Location1 is encoded. Since the information regarding truckA's initial state is associated with Location1, it should be available for later recall. However, information associated with Q2 or Q3 (both Location2) may be lost due to overload. Note, it is predicted that both pieces of information will be available but if overload does lead to loss then it is either the answer to Q2 or Q3 that may be lost (there is no good theoretical reason to decide which), but not both. Generally, then, with no linguistic biases, Q1 should always be answered correctly but either Q2 or Q3 may be wrong.

From the linguistic perspective, Q1 may elicit an incorrect response because the pastness of the question would be identified with the sub-clause associated with the object, in which case the answer to Q1 would be the same as the (correct) answer to Q2 (i.e. Object2). The same bias would apply to Q3. Instead of the correct Object3, children would return
Object4 as an answer to Q3. Thus, with object-centred bias as a single factor Q1 = Q2 = Object 2 and Q3 = Object4. If the representation addressed by Q2 is not available (as a result of loss due to overload) but the object centred bias exists, then the answers to all questions should be identical but in this case they will reflect truckB’s final state. This is because children are biased towards (truckB) and the only available representation associated with this truck is that of its final contents (Object4). If the representation addressed by Q3 is lost then the outcome would be the same as that of object centred bias only, i.e. Q1 = Q2 = Object2 and Q3 = Object4. With this outcome there is no way of establishing whether there is an overload effect in addition to the object-centred bias. If such an outcome is observed than further experimentation will be required. With linguistic biases then, Q1 and Q3 are both expected to be consistently wrong. Generally, Q3 is of no real theoretical significance with respect of the linguistic hypothesis because this hypothesis is already tested by Q1, and because structure of Q3 is further removed from the structure of the 'think' question in the SB design than the structure of Q1. Q3, however, is theoretically significant with regard to the overloading factor and this was the reason for its inclusion. Table 7.1 summarises the above predictions. The Table lists the possible outcomes and the factors that may combine to produce them.

Table 7.1
A summary of predicted outcomes and factors contributing to these outcomes

<table>
<thead>
<tr>
<th>FACTORS CONTRIBUTING TO OUTCOME</th>
<th>OUTCOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No biases; No overload effect</td>
<td>1c, 2c, 3c</td>
</tr>
<tr>
<td>2. No biases; Yes overload effect - Q3 (Object3) lost</td>
<td>1c, 2c, (3w -&gt;Object4)</td>
</tr>
<tr>
<td>3. No biases; Yes overload effect - Q2 (Object 2) lost</td>
<td>1c, (2w -&gt;Object4), 3c</td>
</tr>
<tr>
<td>4. Object-centred bias only</td>
<td>(1w-&gt;Obj2), 2c, (3w -&gt;Obj4)</td>
</tr>
<tr>
<td>5. Object-centred bias; Overload effect - Q3 (Object3) lost</td>
<td>(1w -&gt;Obj2), 2c, (3w -&gt;Obj4)</td>
</tr>
<tr>
<td>6. Object-centred bias; Overload effect - Q2 (Object2) lost</td>
<td>(1w, 2w, 3w) -&gt; Object4</td>
</tr>
</tbody>
</table>

C= correct; W=wrong

17 There are a further 3 statistically possible outcomes that were not included in the table because they are theoretically implausible. These are: 1c, 2w, 3w; 1w, 2c, 3c; 1w, 2w, 3c. The first is an implausible outcome since we do not expect both the answer to Q2 and Q3 to be lost; and the other two are implausible since linguistic biases (that lead to Q1 being wrong) would affect Q3 in the same way they affected Q1.
7.4 Method

7.4.1 Design

Pre-school children were presented with a story and were then asked 3 questions testing their understanding of temporal distinctions between past and present. The story was embedded in a pretend game about a family that was moving its grocery shop from one town to another. Small toys (2 shops, 2 trucks and 4 types of objects to be moved: dolls, furniture, foods and removal boxes) were used to create an elaborate fantasy in which the child was to play the part of the truck driver. The child's role in this capacity was to move objects between two locations (new-shop and old-shop).

The game started in location 1 in which the new shop and one loaded truck were pre-positioned. The truck could contain one of the four object-types mentioned above. The rest of the experimental objects and props were placed in location 2, with the 2nd truck containing one of the three remaining sets of objects and the old shop housing the last two. Each child had to carry truckA-object1 from Location1 to Location2. On arrival in Location2, they had to unload both truckA and truckB and then reload the trucks with the objects that were initially located in the old shop, one set of objects per truck. Finally they had to carry truckB-object4 back to Location1 where they were asked the test questions. The questions were asked immediately on entering Location1 and before the child had a chance to reach the 'new shop' setting. The experimental settings at different stages of the event are presented in Table 7.2

<table>
<thead>
<tr>
<th>Table 7.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental settings at different stages of the truck event</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location 1</th>
<th>Initial State</th>
<th>Intermediate State</th>
<th>Final State</th>
</tr>
</thead>
<tbody>
<tr>
<td>'NEW'</td>
<td>New-shop TruckA +Object1</td>
<td>New-shop TruckB +Object4</td>
<td></td>
</tr>
<tr>
<td>Location 2</td>
<td>Old-shop+(Object3 and Object4) TruckB+Object2</td>
<td>Old-shop; Object3; Obj4; Obj2; Obj1; truckA; truckB;</td>
<td>Old-shop+(Object3 and Object4) TruckA+Object3</td>
</tr>
</tbody>
</table>

In order to eliminate a possible truck effect due to one particular truck being more salient than the other, the association between a particular truck and a given location was counterbalanced such that each truck was placed in the starting location of half of the trials.
Similarly, the position of the different objects was varied, and the story slightly modified to accommodate these variations. Since the initial state of truckA and the final state of truckB were the two crucial positions in the experiment - the former as the main test target for the bias hypothesis, and the latter as the most probable interference item - it was ensured that each object appeared in these positions at least once. The contents of the remaining positions (final state truckA and initial state truckB) was contingent on the first two choices. Four configurations were chosen as the minimum necessary to control for an object-type effect. These are presented in Table 7.3.

| Table 7.3 |

Initial and Final state of trucks in each configuration.

<table>
<thead>
<tr>
<th>Configuration 1</th>
<th>Truck A Initial state</th>
<th>TruckA Final state</th>
<th>TruckB Initial state</th>
<th>TruckB Final state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration 2</td>
<td>Food</td>
<td>People</td>
<td>Boxes</td>
<td>Furniture</td>
</tr>
<tr>
<td>Configuration 3</td>
<td>Boxes</td>
<td>Furniture</td>
<td>Food</td>
<td>People</td>
</tr>
<tr>
<td>Configuration 4</td>
<td>People</td>
<td>Boxes</td>
<td>Furniture</td>
<td>Food</td>
</tr>
<tr>
<td></td>
<td>Furniture</td>
<td>Food</td>
<td>People</td>
<td>Boxes</td>
</tr>
</tbody>
</table>

The test questions interrogated the children's knowledge of the contents of the trucks at different points in time. Each question contained a truck variable, a content variable and two past auxiliaries:

1. The truck that you carried, what was in it? - truckA’s Past state - Apast
2. The truck that you are carrying, what was in it? - truckB’s Past state - Bpast
3. The truck that you carried, What is in it now? - truckA’s Present state - Apres

The first two questions inquired about the initial state of the trucks. The third addressed truckA’s final contents. This question was included as a memory control to test the overloading hypothesis. The final content of truck B was not addressed since it was directly visible.
There are two different temporal distinctions that the child was required to make in order to answer the test questions correctly. First is the distinction between the past (initial) and present (final) states of each truck. Second is the distinction between past and present trucks. Since questioning took place at Location 1, the final state at this location was at that point considered to be the present state for the child. TruckB was, therefore, the truck featuring in the child’s present and truckA in the child’s past. Thus, answering Q1 and Q2 correctly would suggest that the child distinguishes between past and present truck and past and present state. Since these questions were crucial for our primary experimental question, i.e. object centred biases in comprehension of questions, the order of these questions was counterbalanced such that half the children received Q2 first and Q1 second.

The independent variables are:
1. Question type - Three levels: Apast, Bpast and Apres; within subjects variable.
2. Question order - Two level: Order1 and Order2; between subjects variable.
3. Configuration - Four levels; between subjects variable.

The dependent variable is the frequency of correct responses within the various experimental conditions.

7.4.2 Subjects

The subjects were 32 nursery school children including 18 girls and 14 boys and ranging in age from 3:3 to 4:5 (mean age - 4.1). Sixteen children were randomly assigned to each order condition with the only restriction that they be English speaking monolinguals. There were 10 girls and 6 boys in the Order1 condition (mean age = 4:1) and 8 girls and 8 boys in the Order2 condition (mean age = 4:0). The children were of varying socio-economic backgrounds, drawn from one of 3 nursery schools in the Camden area of London. Two additional children were excluded for responding with ‘I don’t know’ to all questions, and three others for providing non-classifiable answers such as ‘toys’ or ‘things’.

7.4.3 Materials

A number of pretend toys were used to create a rich and engaging fantasy for the children. The toys included a ready made set of a pretend shop from the 'Sylvanian family' range. The set included a village shop, groceries such as jars, bottles and tins, and a variety of shop furniture (counters, shelves, cabinets and small accessories e.g. a till). A second shop was
constructed out of a cardboard box. The cardboard shop was similar in structure to the ready
made one, but it was painted in a bright green colour instead of the original's pale yellow. Two
toy trucks, of similar size, were used as the removal vans. The trucks differed in terms of
shape, colour and the material from which they were made. One truck was a yellow metal
truck and the other was an orange plastic truck. Small sample boxes of cosmetic products cut
in half and painted brown were used as removal boxes. The story characters, the Smiths,
included two adult dolls and two child dolls. A picture of the Smith family was cut out of the
box in which these dolls were packed, and was positioned in the first (new shop) location to
be used as part of the introduction to the story. A screen was used to separate the two
locations. The procedure was tape-recorded and transcribed.

7.4.4 Procedure

Prior to testing, the experimenters became acquainted with the children by joining in
on the nursery's routine daily activities. A secluded area (usually the staff-room) was then
prepared for the running of the experiment. First, a screen, dividing the room into two separate
areas, was positioned such that one area was not visible from the other. These areas served as
the new-shop and old shop's locations. A shop and a truck were then placed in each location.
Location1, the location of the new shop, included the ready-made shop from the Sylvanian set,
the picture of the Smiths family, and a truck containing one of 3 possible contents (e.g.
configuration1- food). Location2, or the old shop location, included the constructed shop and
the 2nd truck. Two of the three remaining object types were positioned in the 'old' shop (e.g.
people, furniture) and the third was pre-loaded on truckB (e.g. boxes).

Children were taken individually to the new-shop (Location1) by Experimenter1. In the
New-shop location they were told about the Smith family who were moving their grocery shop
from one town to another and who needed a new truck driver to help them with the move. The
picture was used at this introductory stage to anchor the initial abstract details in some tangible
reality, and to focus the children's attention on the story. The children were then asked to
assume the truck driver's role and help the Smiths with their move. In their capacity as the
truck driver, the children had to carry truckA+object1 to Location2. Experimenter1 then
escorted the child to Location2 where the second experimenter took over. In Location2 they
had to unload both trucks and reload them with the objects that were initially positioned in the
old shop. Children were helped by Experimenter2 in both the unloading and reloading of the
The trucks were first unloaded and then reloaded and each of these actions was carried out jointly by Experimenter 2 and the child. In both locations the children’s attention was drawn to the pre-loaded objects in the truck. Each object-type was named if the child did not spontaneously identify it. Following the reloading of the trucks, the children carried truck2+Object4 back to the new-shop in Location 1. On entering the allocated area for Location 1, and before they had a chance to reach the new shop and put the truck down, children were presented with the test questions (by Experimenter 1). For each configuration, a different reason was given for TruckA+Object1 to be returned to the old location. The stories for each configuration can be found in Appendix 7.1.

7.5 Results

The children’s responses to the test questions were categorised as either ‘correct’ or ‘incorrect’. Within the ‘incorrect’ category, children could potentially return one of four alternative responses. They could either respond with 'I don’t know', or they could default to one of the three remaining event-items. I will first analyse the frequencies of correct responses in relation to the different variables and then examine the types of error made.

Table 7.4 presents the frequencies of correct responses, broken down by question type, question order and configuration.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Order1 - Apast first</th>
<th>Order2 - Bpast first</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Apast</td>
<td>Bpast</td>
</tr>
<tr>
<td>Configuration 1</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Configuration 2</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Configuration 3</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Configuration 4</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Inspection of the data revealed little effect of configuration. Response trends were quite consistent across all levels of the configuration variable (see Table 7.4). Consequently the data
were collapsed and the configuration variable was excluded from further analysis. Table 7.5 presents the frequencies of correct responses when the configuration variable is ignored.

<table>
<thead>
<tr>
<th></th>
<th>Apast</th>
<th>Bpast</th>
<th>Apres</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order 1</td>
<td>12</td>
<td>1</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Order 2</td>
<td>11</td>
<td>11</td>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>12</td>
<td>16</td>
<td>51</td>
</tr>
</tbody>
</table>

Table 7.5

*Frequencies of correct responses as a function of question type and question order*

Overall the Apast question elicited the greatest number of correct responses whereas the Bpast question the least. A Cochran Q Test for related designs showed these differences to be significant ($Q = 7.44; d = 2; p < 0.025$). While the differences within this variable are significant, the pattern of responses does not support the linguistic hypotheses. It was predicted that an object centred bias would result in a low number of correct responses to the Apast and the Apres questions, and a high number of correct responses for the Bpast question (Outcome 4; Table 7.1). The data, however, reflects a trend in the opposite direction. On the whole, children were more likely to respond correctly to both the Apast and Apres question than they were to the 'B past' question. This trend corresponds most closely to the situation in which the effect of overload leads to loss of information associated with the Bpast question (Outcome 3; Table 7.1). However, when the data are analysed in relation to the order variable the picture that emerges suggests a somewhat different story. Inspection of Table 7.5 shows that the question type interacted strongly with question order. The number of correct responses for the Bpast and Apres questions was dependent on the order in which the questions are asked. Note, however, that there was no main effect of order. The total number of correct responses for both levels of this variable are practically identical. Nevertheless the order in which the questions were presented turned out to be crucial for the frequency of correct response for the Bpast and the Apres questions. A cross-over interaction is clearly evident in Figure 7.1.
When the Apast question was presented first (Order 1) all children, but one, gave the wrong answer to the Bpast question. They did, however, respond correctly to the Apres question, the frequency of correct responses for this question being the same as the frequency correct for the Apast question (12/16 in both conditions). This pattern was reversed when the Bpast question was asked first and the Apast second. In this condition both Bpast and Apast question were answered correctly, but this time the Apres question produced a majority of wrong responses. The effect of Question order on responses to the Bpast and Apres questions were both significant and ($\chi^2 = 13.33$, df = 1, $p < 0.001$ and $\chi^2 = 8.0$, df = 1, $p < 0.01$ respectively).

In order to examine the pattern of errors, the data for each order condition were cross-tabulated in a 3*5 matrix (Table 7.6 and Table 7.7). The columns in the matrix represent the 3 test questions, and the rows represent potential answers.
Correct answers are located on the diagonal (highlighted). As already mentioned, Order1 yielded correct answers to Apast and Apres question, and wrong answers to the Bpast question; whereas Order2 yielded correct answers to Apast and Bpast questions, and wrongs answers to Apres. Most strikingly, when children could not answer either the Bpast or the Apres questions, they systematically defaulted to a Bpres answer (no. in bold). This pattern of error is the only systematic pattern in the data. The remaining errors show no systematic pattern and are most likely to reflect random noise. No child gave the same answer to all questions and only 6 of the 32 children (3 in each order condition) gave the same answer to two of the questions. In 4 cases there was the incorrect Bpres, and in the remaining two it was ‘don’t know’.

To sum-up, in the Order1 condition answers to Apast were correct, Bpast produced Bpres answers, and Apres was correct; whereas in the Order2 condition answers to Apast and Bpast were correct, but Apres produced Bpres answers. Thus, Order1 produced the pattern of response predicted by Outcome 3, and Order2 produced a response pattern that was predicted by Outcome 2.

7.6 Discussion

The results did not support the linguistic hypothesis. Children did not show any object-centred biases in their treatment of the past sub-clauses in the questions. Quite the reverse. The best performance was associated with the question that was predicted to produce a majority of wrong responses if such biases existed, i.e. Apast. Moreover, the level of performance on the Bpast and the Apres questions was found to be contingent upon the order in which the questions occurred. Answers to the Bpast question were wrong in Order1 (Apast first) and correct in Order2 (Bpast first), and answers to Apres were correct in Order1 and wrong in Order2. These results rule out a linguistic explanation for the data in this study as well as for the ‘reversed’ pattern of response in the SB task. Whatever linguistic biases exist, they should be consistent across question-order conditions. There is no theoretical reason to assume that linguistic processing should be disrupted or affected by order of presentation. It is either the case that children understand the questions correctly or they don’t, and the data suggest that they do.

The problem then, seems to be associated with the memory system and with the availability of the representations that the test questions were targeting. I suggested in the
Introduction that overloading the child's processing capacity (space and speed) may lead to some loss of information. However, if that information were to be lost, it was predicted that either the Bpast or the Apres information would be lost but not both. As it turned out, there was an overload effect, and although these two items were never lost together in the same condition, each was systematically absent on one of them. In both conditions, the information lost was the information associated with the question that immediately followed the A past question.

At the first level of analyses, it appears that accessing the answer to the A past question is somehow interfering with the information that is required for answering the question next in line. The position of this question (in the overall order) determines the stage at which this interference occurs and, consequently, the specific item that is affected. I will later suggest that retrieval of the record containing the answer to the A past question leads to selective destruction of the information that is being encoded at the time retrieval is initiated. But before I move on to discuss encoding (or on-line processing) and retrieval (of records) procedures, and the way these may combine to produce the observed effect, I should say a few words about the structure of the truck event. A tree structure of the truck event is outlined in Figure 7.2.

**Figure 7.2**
Temporal and hierarchical organisation of the truck event.

The temporal structure of the event is represented by horizontal arrows and the hierarchical structure by vertical arrows. The event is segmented in terms of locations, each location consisting of the scene's initial setting and acts associated with that location. The
actions and objects identified within each location are those actions and objects to which explicit reference was made and which, it can be assumed, were attended to. Event details that were not referred to (e.g. the location's final setting) were not included since it could not be established with any degree of confidence whether or not they were attended to. The settings in both locations specify the actors and the initial state of objects. The actions (e.g. unload) specify the objects on which they are executed (e.g. truckA), and the outcome, or final state (e.g. truckA, Object1). The containment symbol (+) and the associated contents in Location2 are in brackets since it cannot be determined apriori whether an action's initial state is represented. This is a particularly relevant concern since the answers to both question 1 and 2 can be extracted from these representations. The boxed items are the test targets.

The event structure suggests natural points of segmentation for record formation, which, in turn, reflect the structure and contents of the resulting records. I have already assumed (in Chapter 4) that changes in location trigger such closure. Other variables may include changes in protagonist, the conclusion of an action sequence and the strength of links between sequences. A single action sequence must be a basic event unit to be found in a record. The number of such basic units would be determined by the degree of temporal variance and by capacity. However, rather than presuppose the size of records and hence the number of records that might have been created from the truck event, I will look at a number of alternatives. The only presupposition I am making is that Location1 information was encoded in a record as a result of the change to Location2. Segmentation into records of subsequent information is rather less obvious for two reasons. First, recall that the children were presented with the test question immediately on entering the area allocated to Location1, and before they reached the 'new-shop'. Thus, the change back to Location1 was not completed, and therefore a record of Location2 information may not have necessarily been formed. Second, since the event was structured such that most of the actions took place in Location2, it is possible that Location2 information was segmented into two records. Between them, these two assumptions yield 4 possible scenarios. These are outlined in Figure 7.3. In the figure HR = a headed record; #r a potential record; #r2 refers to the first half of Location2 sub-event, (i.e. 'unload' actions) this subsection contains the Bpast answer; #r3 refers to the second half of Location2 sub-event, (i.e. reload) and it contains the Apres answer.

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18 A more complicated version would specify additional details such as the actor performing the actions. However, for this discussion such details are not directly relevant and have no consequences for the discussion of the results. Therefore, the structure was kept simple, emphasising only the necessary information.
Figure 7.3
Creating records of the event - four alternative scenarios

First, if the change back to Location 1 triggered record closure, and if the child's capacity was such that she was able to maintain all Location 2 information until the change in location triggered closure, then there will be a single record of Location 2 information which contains the \textit{Bpast} and \textit{Apres} answers. This scenario, however, will either lead to forgetting of both items, if the record is blocked by HR1 (which in fact is not theoretically viable since HR(2/3) is more recent, and also because the headings of these two records should be different); or it will result in three correct answers in both order conditions. The data clearly falsify both these possibilities.
Second, if the change to Location 1 triggered closure, and if limitations in capacity necessitated an additional segmentation, then there will be two records of Location 2 information. The completion of the unload actions, which is the next level down the hierarchy after location, would be a natural point of segmentation. Thus, the Bpast answer is in record HR2 and the Apres answer in HR3. In order to produce the observed pattern of results, these records must be selectively blocked. It may be the case that HR2 and HR3 share similar headings since they are both associated with Location 2. This could potentially lead to blocking but only of the less recent record, i.e. HR2, in which case answers to Bpast will always be wrong and answers to Apres always right. If, on the other hand, the headings are different enough to be distinguished than both questions should be answered correctly. The data again do not support either of these conjectures.

The first two scenarios assume that all information was consolidated in records. I could have dismissed both at the out-set since ‘forgetting’ of consolidated information can only be due to blocking of records, not overwriting (KA3 Chapter 3), in which case the pattern of interference would be fixed. In other words, if any existing record is blocked by another record, we would expect blocking to be maintained across the order conditions. Nonetheless, I have detailed them because they provide the clues with which to resolve the puzzle. First, the observed pattern of loss could not be achieved if the two crucial event items resided in the same store. They must be located in different stores. Second, the circumstances leading to loss must involve a dynamic stage of information processing rather than a fixed one. Putting it another way, since the option of retrieval failure due to blocking has been ruled out, it must be the case that the information was lost during encoding. If so, then both crucial items of information were still being actively processed at the time the interference occurred. However, given that these two items must also reside in different stores if they are to be independently lost, then it must be the case that there are two on-line buffers that keep these items apart and in this way allow selective overwriting of each individual item independently from the other.

To recap, two requirements must be met to produce the observed pattern of loss:
1. Bpast and Apres are in different stores
and
2. Bpast and Apast are still being processed at the time of interference.

But this will become clearer as I discuss the remaining two alternatives both of which involve loss of information in the on-line buffer.
The third scenario in Figure 7.3 depicts the situation in which limitations in capacity necessitated an additional segmentation for Location2 information (i.e. a record containing the 'unload' actions, which includes Bpast, has been created), but the change to Location1 did not trigger closure (thus, the 'load' actions, including Apres (#r3), are still in the on-line buffer). This results in a situation that satisfies the first requirement but not the second. Thus, the Bpast and the Apres answers are in two different stores (i.e. a record and the on-line buffer respectively), but Bpast has already been consolidated. Bpast, therefore, would be answered correctly in both conditions, whereas Apres (#r3), which is in the on-line buffer, can in principle be lost. This pattern is also not supported by the data. However, as it is the simplest example of destructive update I will use it to set the foundation for my explanation of the results. Figure 7.4 depicts the stages leading to destruction of information in the on-line buffer. The HR processing model is used to hand simulate the processing stages in Condition1. Each frame in the Figure represents a single processing cycle.

Figure 7.4

**Figure 7.4**

**SINGEL BUFFER - SCENARIO 3**

**PART OF LOCATION2 INFORMATION (#r2) IS ALREADY CONSOLIDATED**

Cycle 1 - answer not found in buffer; LTM search prevents HR3 formation

Cycle 2 - R1 retrieved and overwrites information in buffer

In condition 1 Q1 and Q2 can be answered, but Q3 cannot be answered
Condition 2 is same as 1 but this time R2 interferes with HR3 formation
Cycle 1 shows the point just after the first question is asked. At this point the on-line buffer contains #r3, the question and a few current state variables (not depicted). LTM contains HR1 and HR2. In Cycle 1, the evaluator scans the on-line buffer and signals the description formation system to initiate a search (D1). In the next cycle, a matching heading is found (H1) and the associated record is accessed and retrieved into the on-line buffer. Consequently, #r3 information, which is still in the on-line buffer, is overwritten before it has a chance to be dispatched as a record. Here, I am making the assumption that dispatching of records from the on-line buffer and retrieval to the on-line buffer are inverse operations of the same process, and therefore cannot occur in the same cycle. In Condition 1, Apast and Bpast will be answered correctly but Apres will be lost. The same outcome will be produced by Condition 2 but this time the destructive update will be caused by the retrieval of HR2. As already pointed out, the data does not support this scenario.

Scenario 4 in Figure 7.3 describes the situation in which no records were created from location 2 information. This is similar to the situation described in the first scenario, as both relevant items are located in the same store. The only difference is that they are both in the on-line buffer instead of in a record. Thus, scenario 4 satisfies the second requirement, as both items are still being processed, but it does not satisfy the first. The processing stages (depicted in figure 7.5) are the same as in the previous analysis with the exception that the on-line buffer now contains #r2 as well as #r3. Under these processing conditions, retrieval of HR1 results in destructive update of both pieces of information. Condition 1 then, will yield correct answers only to the Apast question, the answers to the other two will be lost. Condition 2, on the other hand, will lead to all answers being correct, because the first question in Condition 2 (Bpast) does not require retrieval, it is directly output from the buffer. Thus, destructive update does not occur and dispatching is not blocked by the retrieval process.

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19 I have already assumed that retrieval involves the copying of the accessed record into a buffer (Chapter 3). Two reasons were given that favour copying into a buffer over direct access. First, copying allows for integration between old and new information, without modification of old records. Second, it allows the search process and the interpretation process to be independent.
While this scenario is not supported by the data, it is the only one in which the order variable can be shown to influence performance. This, I suggest, is because requirement 2, the active encoding requirement, was met at the time the first question was asked. As both items of information were still being processed at that time, they were both sensitive to interference from retrieval, which is associated with the Apast question. The position of this question in the overall order determines when retrieval occurs and whether loss or consolidation take place. Therefore, differences in this question's position should produce different response patterns between conditions. This, however, is only possible if encoding and consolidation of the relevant information is not yet completed when the first question is asked. On the other hand, since the two crucial items are located in the same store, they are either lost or consolidated
together and, therefore, performance on the corresponding questions will be consistent within each condition. To create differential loss of information within conditions as well as between conditions, these items must be segregated in two different buffers. And this leads me to the fifth and final option in which both the independent stores and the active encoding requirements are met.

The fifth scenario considers the situation in which the crucial items are still being processed but each is located in a different short term store. Figure 7.6 and 7.7 portray the processing cycles for each condition in this scenario. The additional buffer is postulated as an Interpreter buffer and will be referred to as the ITP buffer. As both buffers are involved in on-line processing, the original buffer, which subsumed all on-line storing functions, is now specified as the Current State (CS) buffer. In the next section I will discuss in detail the function of each buffer and the type of information each is storing. In general, however, the CS buffer is the original post attentional buffer holding relatively unprocessed propositional information. The information in the ITP buffer consists of complex propositional structures, which are the product of the interpretation stage, and of copied LTM structures, i.e. retrieved information.

Figure 7.6 depicts the processing cycles for Condition1 (Apast first). The first cycle represents the processing stage immediately after the first test question is asked. At this point the more recent event occurrences (i.e. #r3 - Apres) are in the CS, and the less recent event occurrences (i.e. #r2 - Bpast) in the ITP. During the first cycle the evaluator scans the buffers for the answer and signals the Description Formation System to initiate a search (D1). In the next cycle a matching heading (H1) is found and R1 is retrieved into the ITP and overwrites #r2. A correct answer is provided. In the third cycle, (not depicted) the second question (Bpast) is asked and #r3 is transferred into the ITP. Next, the evaluator and D1 unsuccessfully scan the buffers and LTM respectively, but the answer to this question (Object2) is not found. At the end of this cycle only a wrong answer can be output. The hand-simulation does not predict which wrong answer is output, although the data indicated that children defaulted to CS information (Bpres, which was directly observable). The third question will be answered correctly since #r3 was not updated and the dispatching of #r3 as a record was not blocked.
In Figure 7.7 the processing stages in Condition 2 are simulated. In this condition the 1st question is Bpast and it is directly output from the ITP buffer. When the second question
(Apast) arrives, #r2 has already been dispatched as a record and #r3 has been moved to ITP. Thus, when retrieval is initiated in response to the second question, it is #r3 that is updated and consequently lost.

**Figure 7.7**

**DUAL BUFFER - CONDITION 2**

In condition 2 Q2 can be answered; Q3 cannot.
There are two final options to consider. First, if the initial states of actions are encoded then the answer to the Apast question will not necessitate retrieval, in which case answers to Apast and Bpast should be consistent within conditions. Since this pattern was not observed, it may be concluded that initial states of actions are not encoded in which case it is the setting information in Location2 that provides the answer to Bpast. Second, it may be that more than two records were created from Location2 information. For example there may have been a record for each action type (e.g. unload) and for each truck (e.g. truckA). If this were the case, then it is only Apres information that would be lost since Bpast is already in a record; and it will be lost only in Condition1 since it is less recent that 'truckB load' and will therefore reside in the ITP when the first question is asked. This option too is inconsistent with the data.

The only possible scenario that could have produced the observed pattern of data is one in which Location2 information (the Bpast and the Apres answers) was still being processed in a dual buffer system. Thus, at the time the first question was asked only a single record (HR1 - Location1 information) was created from the truck event. This record contained the answer to the Apast question, and it was readily accessible independent of the position of this question in the overall order. However, accessing the answer to this question interfered with the information that was required for answering the question next in line (Bpast in Condition1, and Apres in Condition2). This selective pattern of interference and loss could only have occurred if Location2 information was still being processed at the time of test, and if the crucial items of information (i.e. Bpast and Apres) were residing in different on-line buffers.

Thus, 3 further assumptions regarding the model (MAs) can be defined on the basis of this explanation:

MA10: There are two on-line buffers CS and ITP.

MA11: The CS is a post attentional buffer, storing on-line information.

MA12: The ITP is a post interpretation buffer, storing integrated on-line information and record information (e.g. a GER, or similar past experience) that is important for interpretation.

And one existing MA can be modified:

MA9: Retrieved records are copied into the ITP buffer (modification in italics).

In the next chapter I will implement these assumptions in a computer simulation of the truck study, but first I will specify the differences between the CS and ITP in more detail.
7.7 A Dual Buffer system

The possibility for the existence of a second working memory, or on-line buffer in my terminology, has been suggested as long ago as 1979 by Spilich, Vesonder, Chiesi, and Voss. Testing text processing for domain-related information in individuals with high and low domain knowledge, they found that the model which best fitted their data included either an additional working memory, or the idea of an active structure in LTM working in conjunction with the traditional single working memory system. The authors were concerned with how high-level knowledge structures such as scripts affected later recall. Using baseball as their knowledge domain, Spilich et al. tested recall of a text describing a fictitious game by individuals with low and high baseball knowledge. The hypothesis was that high knowledge (HK) individuals would process information more effectively as they would have a knowledge structure (a GER) to refer to:

"primarily through the operation of a working memory system that keeps track of the values of the goal related variables i.e. they will retain the most salient macrostructure in working memory and will be able to relate it to the input information." (Spilich et al., 1979, p. 278).

The authors predicted that HK individuals would have better overall recall, and that their memory accounts would contain more script-related information. They found that HK individuals recalled more information that was script related, they were more likely to integrate sequences of script-related actions, and they recalled information in the appropriate order. They also recalled more setting information that was relevant to the goal structure. In contrast, low knowledge (LK) individuals recalled more information and actions not related to the goal structure - their recall accounts were like "a free recall list excluding a recency effect" (p. 284). For example, LK recalled 25 names of players in comparison with HK who recalled only 9 names, although HK recalled more about the actions of particular batters.

To provide a more quantitative evaluation of their theory, the authors borrowed Kintsch and van Dijk's (1978) model of text processing, and fitted their data to this model. The original model assumes that text is processed in terms of processing units (also referred to as cycles) which are defined as propositions existing within a sentence. Two types of propositions are defined within the model: microstructures, which are arrived at via propositional analysis of the text, and macrostructures, which involve propositions of the text or derived from the text that are related to a hypothetical macrostructure. In the Spilich et al. study the processing units were defined as game episodes, the macrostructure was the script structure and the
microstructure was the on-line information. The model then goes on to specify four parameters \( s, p, m \) and \( g \). The \( s \) parameter is the number of propositions which are carried (or kept) in working memory from one cycle through to another. Which propositions (either macro or micro) are carried over to the next cycle is determined by recency and importance, or in my terminology - relevance. The \( p \) parameter defines the probability of recall of micro propositions, and the \( m \) parameter is the probability of recall of macro propositions. The \( g \) parameter is not used by Spilich et al. as they suggest that its role is minor and irrelevant.

Once a model had been established, sets of equations were generated which related the \( p \) and \( m \) parameters to the recall of particular propositions, and an estimate of parameter values were then obtained using the STEPIT procedure (Chandler, 1965). The assumption was that for each new cycle in which a given proposition occurs there is an increase in the probability of that proposition getting into LTM. Using this model and the STEPIT procedure, it was found that the best fit for the data was obtained with \( s = 2 \). This value was the best fitting value for both HK and LK groups. This result was surprising, because the original expectation was that the \( s \) value for the HK group would be greater since their existing knowledge structure - the script - should enable them to hold more information in working memory. Spipich et al. attributed this unexpected result to the absence of a qualitative difference in the treatment of macro and micro propositions in the original Kintsch and van Dijk's model. However, since the HK and LK difference should reflect a difference in the processing of macrostructure propositions, the authors went on to develop a number of models incorporating macrostructure operations.

First they assumed a single macro propositional buffer that would carry macro propositions necessary for the interpretation of the game. They then developed an additional parameter that denoted the probability of macro propositions being carried over from one cycle to another. They applied this revised model to the data and found no improvement. They then attempted to manipulate the number of macro propositional slots within the buffer, but again failed to achieve a better fit. Finally, an additional buffer was added to the model such that the original \( s = 2 \) micro proposition buffer was combined with the assumed macro proposition buffer. This new model provided the best fit to the data.

There were two variations on this dual buffer model. In the first, each buffer was associated only with its corresponding proposition-type (i.e. macrostructures only in the macro buffer, and microstructure only in the micro buffer). In the second, macro propositions were
allowed to have a micro proposition status and could, when required, be carried in the microstructure buffer as well as in the macro buffer. This second version provided the best fit to the data. The correlation between the actual data and the data predicted by the best-fitting model was 0.73 for the HK group and 0.83 for the LK group. None of the other models provided significant correlations for the HK group; although two other macrostructure models produced correlations significant at the 0.05 level for the LK group.

The authors suggest two possible interpretations of the results from their modelling. First, that there may be two interacting buffers, one handling macrostructure information and the other handling more local and adjacent microstructure information. The latter buffer is the typical finite capacity, working memory structure. The former also may be assumed to have a finite capacity, but it seems to be capable of holding macrostructure information during the processing of microstructure information. The fact that the second version of the model provided a better fit may suggest that macrostructures can also be found in the micro propositional buffer. In the other interpretation, the macrostructure buffer is not really a working memory structure, but instead it represents LTM in which the appropriate macrostructures are kept on as an active list and thus may be readily accessed. Spilich et al. conclude: "The present results do not provide a basis for choosing between these alternatives. However, the findings do point to the need to postulate some type of an active system that holds macrostructure information while microstructure information is being processed." (p. 288).

7.7.1 The CS and The ITP

In Chapter 3, I already gave two reasons for proposing that information is not read directly from LTM, but instead the accessed record is copied into a buffer. First, copying allows the integration between old and new information without modifying any existing representations. Second, once the required information has been copied, the long-term-store can be disengaged and thus made available for new searches (if necessary) without necessitating the loss of the previously retrieved information. This way the search process and the interpretation process can be independent. This independence is particularly important for the smooth operation of any interpretation process that relies on long-term representations (e.g. GERs). If the two processes were dependent then any search process could potentially disrupt the interpretation process. This assumption alone, makes a good argument for the
incorporation of an additional buffer into the model. It seems likely that the capacity of a limited capacity, post-attentional buffer (now termed the CS) will be too restricted to be able to hold the contents of a record (or even part of it) in addition to the unprocessed (uninterpreted) propositional information. Furthermore, if it is assumed that the CS is always full of information ('overloaded' is its natural state) then every instance of retrieval will result in large chunks of current state information being lost instantly. In order to avoid this another buffer is needed - the ITP - into which retrieved information is copied.

However, irrespective of retrieved information, the truck experiment provided evidence to suggest that an additional buffer is also actively involved in the processing of on-line information. This links with the first reason I proposed for favouring copying of LTM structures into a buffer - it allows the integration between old (LTM) and new (on-line) information without modifying existing representations. The ITP is the space in which such integration takes place.

A distinction between the CS and ITP buffers also allows for selective encoding of attended stimuli. Not all information that enters the CS will find itself in the ITP. Some information in the CS will be lost either because it was not selected for further processing by the interpreter, or because it was overwritten by new information before it had a chance to be processed. In contrast, information in the ITP cannot be overwritten. All information that enters the ITP should, in principle, end up in a record. The only type of loss that can occur in the ITP is loss due to (destructive) updating of information, which occurs when the processing conditions are altered to motivate reorganisation of information.

Information in the CS and information in the ITP

When I discussed the HR model in Chapter 3, I assumed that post-attentional information is already in a propositional format. Now that I have postulated two on-line buffers in the model, and like Spilich et al. (1979), have assumed that one buffer is associated with simple propositions and the other with complex propositions, I must define the type of simple propositions that are allowed in the CS. My original assumption was that only propositions of single items (i.e. a propositional representation is given to either a visual representation of the object 'tube', or to an auditory representation of the word 'tube') are allowed in the CS, but there are no similar representations for the relationships between these items at this stage. This would be fine with objects and agents but what about actions? Actions do not have the same
independence, and consequently the same freedom of definition, as objects and agents do. It is possible to define 'a tube' in isolation without making reference to anything outside its own unique characteristics (i.e. long hollow cylinder) but the same is not true of actions. Actions must be defined in relation to objects and/or agents, they become meaningful only in light of the relationships of which they are a part, e.g. agent X is 'shaking' y; or X (himself) is 'shaking'. The action in these two sentences has a slightly different meaning, therefore, if 'shake' is to be given a propositional representation then the context in which it is carried out must also be represented - either shake (X,y) or shake (X).

Given that actions must be represented in the context of a relationship, the original assumption must be extended to include representations of simple relationships between items. This, however, introduces two additional problems. The first is the problem of defining 'simple': how simple must these relationships be to be a part of CS information, and how complex to be a part of ITP information? The second concerns other types of simple relationships (other than actions) that may, or may not, be included in the CS, e.g. 'a tube is a container'.

First, the question of complexity. Going back to the 'shake' example, the action of shake could be described not only in terms of an agent and an object but also in terms of time, place and affect. Using the SB task an example, a 'shake' action could be expressed in the following way: "E was shaking the tube vigorously in the morning in the quiet-room" and may be formally represented as:

\[ (_x) \text{(shake}(E, \text{tube}, x) \& \text{with}(\text{vigour}, x) \& \text{in}(\text{the morning}, x) \& \text{in}(\text{quiet-room}, x)) \]

(\text{after Davidson, 1967}).

Assuming that such a representation is an acceptable type of CS information, then could we go further to suggests the following representation?

\[ (_y) \text{(transfer}(E, \text{content}, y) \& \text{from}(\text{tube}, y) \& \text{to}(\text{bag}, y) \& \text{in}(\text{the morning}, y) \& \text{in}(\text{quiet room}))? \]

As the 'transfer' event occurs over a certain period of time, and since the CS is assumed to be continuously updated, then it would seem unlikely that the CS could contain a representation that depends on any information being available over time. The 'transfer' representation, therefore, could only be the product of the interpreter. One of the main roles of the Interpreter is that of integrating information. In processing terms this means identifying themes and goals which can then be used to identify the relevant items and integrate them into a coherent event
structure. Formally, this would be similar to setting the existential quantifier (\(\exists x\)).

An existential quantifier, in predicate logic, defines a predicate in which an individual variable 'x' has one or more free occurrences. In line with this definition, an action sentence will be analysed by most philosophers as an n place predicate (4 or 5 respectively in the above examples). Davidson (1967) argues against the view of single predicate analysis of action sentences. He suggests that an action should be treated as an event, and the relations (e.g. at, in) between the different components of the action (e.g. time, place) should be treated as individual predicates. According to this approach, the existential quantifier defines an event (rather than a predicate) and a number of predicates (rather than arguments) all of which are instances of that event.

Using Davidson's analysis, a distinction between the type of information in CS and in ITP can be made on the basis of representations which require an existential quantifier (more than one predicate) and those which don't (single predicate). Thus, a representation that requires an existential quantifier must be a product of the Interpretation process. By this definition the complex representation of the action 'shake' will not be included in CS. Complexity, in this context is accordingly defined in terms of single vs multiple predicates. The CS will have single predicate propositions as its primary input, complex representations in the CS would only be copies from the ITP.

The next issue concerns the type of single predicates. For example, in the context of the SB experiment a tube is a container and it contains something (Smarties or marbles). This may lead to the formation of the following representations:

1. contains (tube, x),
2. contains (tube, Smarties)
3. contains (tube, marbles)

All three examples pass the 'single-predicate' requirement, but they may be different from the following in two important ways.

4. shake (X, y)

First, they may different in relation to the temporal proximity between the predicate's arguments. In terms of temporal proximity, examples (4) and (3) are exact opposites: arguments 'X' and 'y' in predicate (4) occur simultaneously, whereas arguments 'tube' and 'marbles' in predicated (3) could not be further apart as, respectively, they mark the beginning and the end of the SB event. The formation of (3), in this case, will have to rely on a
reconstruction process and must, therefore, be a product of interpretation; (4) on the other
hand is CS material. But where between these two types of predicates should the borderline
be? It seems that the only reasonable answer is that items must occur consecutively if they are
to be included in the same representation in CS. Items that are separated by one or more
elements will have to be pulled together into a single representation, but, pulling together
requires a common denominator (a rule or a function) and this can only be provided by the
interpreter. (reconstruction as in (3) and inference e.g. shake(E, Smarties) are examples of
pulling together of items that are separated in time).

Second, simple predicates may also differ in terms of the source of the representation.
In the contexts of the experiment, (2) depends on previous knowledge while (1), much in the
same way as (4), is directly observable. My assumption is that CS representations are usually
products of directly observable experiences, whereas representations that rely on long-term
knowledge are ITP representations. The CS then may be seen to function as the intermediary
between the external world and the processing system, and the ITP as the intermediary
between the processing system and the internal world. Thus, in the Smarties and the SB tasks,
the belief representation, which is a mental product, is in the ITP from the start, whereas the
reality representation (marbles or a pencil) is initially in the CS, and it is only subsequently
transferred to the ITP where it either replaces the belief representation or is integrated with it
into a single structure.

I can now refine assumptions MA11 and MA12 presented in section 7.5:
MA11: The CS is a post attentional buffer, storing single predicate propositions which are the
products of perception.
MA12: The ITP is a post interpretation buffer, storing complex, multi predicate propositions
which are either the products of interpretation, or the outcomes from retrieval (e.g. a GER,
or a similar past experience).
The next chapter reports a computer simulation of the truck experiment in which these
assumptions, as well as some of the original model assumption specified in Chapter 3, are
implemented.
8. THE SIMULATION

8.1 An Overview

In this chapter I will report a simulation of the truck experiment. The simulation was written using a Prolog based language called COGENT (Cognitive Objects within a Graphical Environment). A small section of the original HR model was implemented paying particular attention to the assumptions associated with the explanation for the truck experiment. The simulation was found to reproduce the empirically observed patterns of response. The modelling work was also fruitful in that it suggested a number of variations on the original design, making specific predictions regarding their outcome. Two of these predictions were empirically tested and the predicted outcomes obtained. I will start by describing the modelling environment - COGENT, then discuss the implementation, and finally report the empirical work that it motivated.

8.2 The COGENT Environment

COGENT is an object-oriented program formally implementing and testing computational models of cognitive processing. It enables the user to create models consisting of interacting buffers and rule-based processes as box-arrow diagrams. Sub-conditions to the rules can be written using Prolog within COGENT. COGENT was written by Cooper (1996) and it is still under development.

8.2.1 Creating a Model

A cognitive model specified within COGENT consists of a set of linked objects. The objects are chosen from a tool bar and placed on a canvas and then links between the selected objects are added. There are 3 main types of objects: Data objects, Buffer objects and Process objects; and two types of links: Send links and Read links. Figure 8.1 depicts a simple model of animal-category identification which I will use as an example to illustrate the operation of
The COGENT environment. COGENT represents data objects as diamonds (Input and Output in Figure 8.1), buffers as ovals (e.g. 'Category Memory') and processes as hexagons (e.g. 'Look-up Category'). An arrow with a pointed arrow-head represents a Send link and indicates the flow of information between objects (e.g. from Input to 'Look-up Category'); an arrow with a dark circle head represents a Read link and indicates that a process can read from a buffer (e.g. the process 'Look-up Category' reads from the 'Category Memory' buffer). Once a model has been created it can be run. Execution occurs in cycles. On each cycle each object operates on the data at its input. The outcome of this operation depends on the particular class of object: a process will transform the data and pass it on as input to another object; a buffer will incorporate the data into its state. All operations in a given cycle occur in parallel.

**Figure 8.1**

*The category identification demo*

In the animal-category illustration, the aim is to identify the category membership of an animal at input, e.g. to identify an elephant (at input) as being a wild animal. Thus, the 'Look-up' process receives an animal name at its input; it then reads the contents of the buffer, which represents semantic knowledge, and if it finds an answer that matches, it sends it to output (A print-out of this simulation can be found in Appendix 8.1)
8.2.2 Data Input/Output

Data objects provide input to the model or record output from the model. An input data object is termed Source (e.g. the arrow-head pointing outwards) and an output data object Sink (e.g. the arrow-head pointing inwards). Data sources are represented as a list of Prolog terms. On each processing cycle the first element of the list is removed from the source and added to the object to which the data source is linked (e.g. the source in the example will contain a list of animal names, an element in this list may contain one or more animal names). This process continues until the list is exhausted. Data sinks record the results from the model (i.e. the answers - e.g. domestic_animal, wild_animal etc.).

8.2.3 Buffers

Buffers store information but they cannot produce output (i.e. they cannot send information). Information is either sent to buffers or read from buffers. When information is sent to a buffer, it changes its state. There are three types of messages that can be sent to buffers: a Clear message deletes all elements from the buffer; +X (where X is a Prolog term) adds the element X to the buffer; and -X removes the element X from the buffer. Buffers have a number of properties which determine the way they behave when they receive information and when they are read. One property determines whether duplicate information can be stored or whether it should be ignored. A second property determines the way in which a buffer's elements are accessed - at random (Random), first in first out (FIFO), or Last in first out (LIFO). A third property specifies whether or not the buffer's contents are subject to decay over time. Finally, buffers can be either of an limited or unlimited capacity ('L' and 'U' on the canvas respectively). When a buffer is of limited capacity, its behaviour on overflow can be specified as Random deletion, First - in which case the oldest item is deleted, or Last where the newest item is deleted. In the example, 'Category Memory' is a buffer of unlimited capacity (representing semantic knowledge) in which the most recent item is accessed first (FIFO). The buffer contains a list of Prolog expressions such as: category(elephant, wild_animal).

8.2.4 Processes

Processes are objects which transform one representation into another. A process can be either Triggered or Autonomous. A triggered process is activated by input signals; it produces output when it receives a specific piece of information (as its input) from another object. In contrast, an autonomous process produces output independent of any input; it is
usually fired by the presence of certain information in a readable buffer. The functioning of a process must be expressed in terms of simple rules. Rules take the form of IF < list of conditions true > THEN < perform list of actions >. Conditions can be Prolog predicates, a predicate provided by COGENT or a condition specifically written by the user. Possible actions are to delete/write some data to/from a buffer and send some data to other objects. Rules can be either refracted or unrefracted. If a rule is refracted, it will only fire once on any set of data. The process in the example contains a single rule. The rule is unrefracted and triggered:

TRIGGER: Animal
IF: category(Animal, Type) is in Category Memory
THEN: send Type to Output

Thus, when the ‘Look-up’ process receives ‘elephant’ as its input, it searches the ‘Category Memory’ buffer for an expression of the type category(Animal,Type) in which the variable ‘Animal’ = elephant. If it finds an expression that fits, it sends the corresponding instantiation of the variable ‘Type’ (i.e. wild_animal) to output.

8.3 General Theoretical Assumptions for the Truck Experiment

The aim of the implementation was to simulate children’s behaviour in the truck experiment and reproduce the observed patterns in the data. For this purpose only those aspects of the model that were relevant in the context of the truck experiment were implemented. These included the buffers and the creation and retrieval of records. In the latter, the main focus was on the interaction between the contents of buffers and; not the retrieval cycle as a whole. This and other aspects of the model that were not directly relevant to the truck experiment (e.g. heading formation) were not considered.

8.3.1 The Truck Experiment

In the truck experiment children were required to recall three event items. These included the initial and final contents of truck A (Apast and Apres respectively) and the initial contents of truck B (Bpast). It was found that the order in which the questions were presented, determined the availability of these items for recall. In particular, responses to the Bpast and the Apres questions where highly sensitive to order. In Condition 1, when the Apast question was presented first, most children gave the wrong answers to the second, Bpast question. They did, however, respond correctly to the Apres and Apast question. This pattern was reversed when the Bpast question was asked first and the Apast second. In this order both the
Bpast and Apast questions tended to be answered correctly, but this time the answers to the Apres question were wrong. In both conditions, accessing the answer to the Apast question seemed to have interfered with the information that was required for answering the question next in line. The position of this question (in the overall order) determined the stage at which this interference occurred, and consequently, the specific item that was being affected. I have suggested that the retrieval of the record containing the answer to the Apast question, led to selective destruction of the information that was being encoded at the time retrieval was initiated. However, this requires that:

1. The item associated with the Bpast question and that associated with the Apres question are both still being processed (and therefore sensitive to loss) at the time the interference occurred.
2. These items are residing in different stores.

This led me to postulate an additional on-line buffer for the HR model - the ITP. In this revised version of the model, the ITP was specified as a macrostructure buffer and the original on-line buffer was respecified as a microstructure buffer and termed the CS. The ITP is the working space for the interpreter, and is assumed to store complex propositional structures that are the products of the interpretation process as well as retrieved record information. The CS, on the other hand, is a pre interpretation buffer, and is assumed to contain simple propositional structures; any complex structures that are found in this buffer are copies from ITP.

Thus, at the time the first question is asked, Location2 information is still being processed (and Location1 information (Apast) is represented in a record). However, different parts of Location2 information are at different stages of processing: the more recent information (the load actions including Apres) is still in the CS awaiting interpretation, whereas the less recent information (the unload actions including Bpast) is already in ITP. If retrieval is initiated at this point (as in Condition1- Apast first) and a record is retrieved into the ITP, then the Bpast information in the ITP is lost. This, however, does not occur if (as in Condition2 - Bpast first) the first question can be accessed directly in the ITP. In this case, the question is answered correctly and the information dispatched as a record to LTM, clearing the ITP for the next lot of event information - the 'load' actions and Apres. However, if retrieval occurs at this point then the Apres information is lost.

This explanation accounts for the pattern of results in the truck experiment, and it also enables us to predict the outcome of the remaining combinations of question order. However,
in the process of hand simulating these outcomes it became clear that I had overlooked one important variable - the creation of (secondary) records of the 'question-answer' information. This became apparent when I was hand-simulating the situation in which the first question could be directly accessed from the CS - i.e. Apres. In this case it was not clear whether the creation of a record containing the Apres information, which was now prioritised by the question, would not lead to destructive update of the information in the ITP (Bpast), or whether the ITP information would be dispatched prior to this record being created. In line with my explanation of the results from the SB studies, in which I have suggested that questions can determine the relevance of information, and in this way shift the processing priority of the system, I would predict the former. However, if it is the case that the creation of the (primary) record of the CS (Apres) information interferes with the ITP information, then the creation of secondary records of the 'retrieved Apast answer' information should produce the same interference.

We know from the 'Mickey' study, as well as from Ratner et al.'s (1991) 'clay making' event (Chapter 2), that questions result in the creation of (secondary) records which can subsequently interfere with recall of the primary records. This general principle - questions lead to the creation of records - would also apply in the truck event. However, since a large chunk of information in the truck study is still being processed at the time of questioning, the creation of such ('answer') records would, in this case, interfere with the creation of the primary records of the experience. The pattern of interference will be identical, but on this explanation it will not be caused by the retrieval of the Apres record but rather by the creation of a secondary record of the answer to this question.

Thus, the Apres record is retrieved into the ITP but it does not replace existing information; it simply co-resides in the ITP with the to-be-encoded primary information (Bpast in Condition 1 or Apres in Condition 2). However, once an answer is output, a record is created that contains only information that is relevant to this answer. The remaining ITP information is then cleared and replaced by the new CS information. As before, this interference will not occur if the answer is directly accessible from the ITP.

Now I can predict the outcomes to all possible question-order permutations (Table 8.1). The general rule is that if a question is answered either from LTM or CS the information in ITP is always lost. Thus, when the Apast question is asked first the Bpast information is always lost - whereas the Apres information is always available. This will be independent of the order of the Bpast and Apres questions; the only difference is that if the Apres question
is asked last (as in the truck event) the answer is retrieved, and if it is asked second then the answer is directly available from the ITP. The same outcome will be obtained when the Apres is asked first, i.e. Bpast is always lost and the other two answers are always available; again this will be independent of the order of the Bpast and Apast questions. Finally, if the Bpast question is asked first then the Bpast and the Apast information will always be available, but the availability of the Apres information will depend on the position of the Apast question. If the Apast question is second (Condition2) then the Apres is lost. If, however, the Apast is last, there will be no interference - the Apres information is accessed directly in the ITP and dispatched as a record. This is the only order in which the answers to all three questions will be correct. Table 8.1 summarises these prediction. The conditions that have already been tested empirically appear in italics, and wrong answers in bold.

**Table 8.1**

*A summary of predicted outcomes for different question-order permutations*

<table>
<thead>
<tr>
<th>Question-order permutations</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1. Apast 2. Bpast 3. Apres</td>
<td>Apast - Correct Bpast - Wrong Apres - Correct</td>
</tr>
<tr>
<td>4 1. Apres 2. Bpast 3. Apast</td>
<td>Apres - Correct Bpast - Wrong Apast - Correct</td>
</tr>
</tbody>
</table>

The conditions that have already been tested empirically appear in italics, and wrong answers in bold.

**8.3.2 Summary of the assumptions for the Implementation**

In short, it is proposed that the interference in the truck experiment was caused by the creation of a record that was motivated by the Apast question; and the pattern of interference observed occurred because, at the time of test, Location2 information was still being processed in a dual buffer system. Thus, a dual buffer model and the creation of records are the two main components in the implementation. Timing too is crucial; since the interference is caused by the creation of ‘question-answer’ records, the point at which a question is asked will determine whether or not interference occurs. Timing, therefore, will be another important component of the implementation.
A dual-buffer model

1. There are two on-line buffers - the CS and the ITP.
2. The CS buffer holds information for the interpreter. The information in the CS is post attentional input information consisting of simple propositional structures. Information here may be wiped out by newly arriving information, irrespective of its importance, if the interpreter cannot attend to it.
3. The ITP can be viewed as the interpreter's working space. The ITP contains post interpretation information consisting of complex propositional structures - either integrated input information or record information.
4. Records are retrieved into the ITP.
5. CS, ITP and LTM are searched in parallel. With this assumption I do not mean that the Describer searches CS and ITP as well as LTM, because the Describer searches for matching headings, and there are no heading associated with the CS or the ITP buffer. The 'search' I am referring to is a consequence of the evaluation process, and it may be more correctly conceptualised as an 'appropriateness' check on the information in the on-line buffers rather than as a search. Since the evaluation process must continuously scan the on-line buffer to ensure the continued relevance of the retrieved record to the current task (DC4), it seems reasonable to assume that when the task changes, or a new task (e.g. a question) is specified, the continuous scanning operation of the evaluation process will identify suitable information in the on-line buffers (if such information exists) and will use it as required. The only addition is that this scanning operation now extends to include the CS.

Creation of records

6. The Parser identifies event goals and relevant event items in the input information (in CS), and integrates this information into complex event structures (in the ITP). It carries out its function using LTM information.
7. Completion of records is guided by the parser and it occurs when:
   (a) an event sub-structure (a branch on the tree) is completed. For example, the change from Location1 to Location2 should trigger record closure.
   (b) the flow of information within event sub-sequence overloads the buffers. In this case natural points of segmentation in the sub-sequence will signal completion, e.g. the conclusion of the unload actions.
8. Inclusion of information in records is a function of relevance (also guided by the parser).
Generally, relevance judgments will depend on event goal. However, certain external factors may override this tendency and shift the processing priority of the system. An example of this would be a sudden danger. Questions will have a similar effect, thus:

9. Questions have priority. A question may prioritise certain event items and consequently alter the organisation of the information that is being processed. This occurred in both the SB and the truck experiments; the test questions affected the organisation of the information that was still being processed, and led to loss.

10. Questions lead to the creation of secondary records. The creation of such records will also lead to loss of on-line information that is not directly relevant to the question.

**Timing**

11. Once a question is asked, no dispatching of records occurs until it is answered. I have not yet mentioned this assumption explicitly, although it was implicit in my explanation. Without this restriction, there would have been nothing to prevent the information in the ITP from being dispatched as a record prior to the creation of the secondary (the Apast answer) record. However, independent of the truck study, given that the CS, ITP and LTM are searched in parallel, there would be an advantage in freezing the dispatching process when a question is asked until the search is complete and an answer is accessed. These assumptions, apart from assumption 6 - the parser's integrating functions, were implemented using COGENT.

**8.4 Implementation of the Truck Study**

Figure 8.2 depicts the model used to simulate children's behaviour in the truck study. The model is designed to create records from the event, and answer questions. Both these functions are carried out by the Interpreter. The Interpreter looks for event relevant information in the CS, which receives input information from the 'Attention outputs' source. Relevant information in the CS is then pulled through and transferred to the ITP where it is integrated into a record using script structures in the ITP. These script structures are provided by the 'LTM Recall' source. The record is then sent to 'New Records' (representing LTM). The interpreter also answers questions. It moves questions from the CS to the ITP where it answers them using information from the CS, ITP or LTM ('New Records'). The answers are sent to the 'Answers' sink.
8.4.1 Dual Buffer System

*Current State* - *The microstructures buffer*

*Data source* - ‘Attention outputs’

The CS buffer receives information from ‘Attention output’. The information is assumed to be post attentional propositional event information. The first task was to characterise the input information to the CS in terms of the type and contents of the representations, and the rate at which information enters the system. As I discussed in Chapter 7, the type of information that is expected to arrive in the CS will consist of single predicate propositions. Single predicate propositions are representations either of single items (e.g. truck(yellow)) or of simple relationships between items (e.g. in(truckA, object)). Only items that occur consecutively can be included in the same representation in the CS. As for contents, I included only the information that was verbally expressed in the experimental
situation, since this is the only information that is certain to have been attended to. Finally, the order and rate at which information entered the system was determined by the structure of the event. Each temporal unit within the event was entered as a single cycle, and items that occurred simultaneously (i.e. within the same temporal unit) were entered in the same cycle. For example, Location1 information was entered as four items on Cycle2, and carrying the truck was added as a single item on Cycle 4. Consistent with this order and rate of entry, the first question arrived at the CS following the child(carry, truck2) information. However, the remaining questions had to have empty input cycles between them in order to allow the previous question to be fully processed.

**Specifications**

The current state buffer stores information for the Interpreter. This information is then used to create records. The CS was specified as a limited capacity buffer capable of holding three items of information at a time. When a new item arrives at the CS the oldest information is overwritten (FIFO). Thus, certain items that may have been attended to may not get into a record; the smaller the capacity the greater the potential for loss.

**ITP - The macrostructures buffer**

*Data source - ‘LTM Recall’*

‘LTM recall’ sends to the ITP information which is used to interpret the CS data. This box is a substitute for assumption 6 (in the previous section) which was not implemented in the model. This source provides the script structures which are to aid interpretation of the input information. In a complete model this would represent the output from a successful search, which would have retrieved a generalised ‘moving’ schema to assist interpretation of the truck event. This structure would then be used to integrate CS information as specific instantiations of script variables. In practice, the specific structures were build into the simulation and presented in the order in which the event occurred. The order of presentation corresponded to the information in the CS with a delay of one cycle. For example, the unload structure is entered on Cycle 7 which is one cycle after all the unload actions entered the CS.

**Specifications**

The ITP is the Interpreter’s working space. It holds complex propositional structures which are the product of the interpretation processes, as well as referent (record) information
which is provided by ‘LTM Recall’. Information in the ITP is kept until a signal to dispatch a record is triggered. The ITP is then cleared in readiness for the arrival of the next information. Clearing the ITP once a record is dispatched was a design consideration, not a theoretical one. The ITP was specified as an unlimited capacity buffer, and there is no good theoretical reason to clear such a buffer. A more appropriate characterisation would involve the decay of information rather than clearing. However, as noted, the parsing functions of the Interpreter were not simulated. This meant that an integrated structure entered the ITP (from LTM recall) on a single cycle and was immediately ready to be dispatched as a record, when in theory, integration of input information into complex structures should occur over a number of cycles. Under these conditions it is impossible to define a decay constant that would produce any meaningful patterns of loss.

8.4.2 Creation of Records and Timing

The Interpreter

The Interpreter creates a record when it detects a complete structure in the ITP. As I have already noted, complete structures are provided by ‘LTM Recall’ and are not integrated by the parser from CS information (this part of the theory is yet to be implemented). Thus, when a complete structure enters the ITP, the Interpreter detects this structure and in the next cycle a record is created. If no questions are in the system this record is dispatched to ‘New Records’ on the next cycle. If a question is detected in the system, then the dispatching operation is frozen until a conclusion to the question is reached. Once a conclusion is reached, the signal to freeze the dispatching operation is cleared.

The Interpreter scans the CS, ITP and ‘New Records’ in search of an answer. If it cannot access an answer directly in the CS or ITP but there is a matching record available in ‘New Records’, the Interpreter retrieves it into the ITP; if a matching record is not available, then the Interpreter sends a ‘no answer’ message to ‘Answer’. A match_record condition in the Interpreter emulates the heading-description match.

When an answer is found, a record is created. In theory, this record should contain the question, the answer, and the structure that provided the answer. In practice, however, the question was not included in the record. This is because Prolog decodes the questions over several cycles and by the time an answer is accessed, the question is no longer available in its original form. Maintaining the original format of a question until an answer is accessed was not an option because it would have made rules fire when they are not supposed to. Thus,
the 'answer' records did not include the question. They did, however, include the structure that provided the answer, unless of course, the answer was directly accessed in the CS. In the latter case the 'answer' record included only the answer. Once the 'answer' record is created, it is dispatched to 'New Record' and the ITP cleared to process new information. Any event information that was lingering on in the ITP and was not relevant to the question is then lost.

Questions and constant state information, such as location and goal, receive preferential treatment by the Interpreter. These types of information are transferred to ITP immediately as they enter the CS, and are maintained in the ITP until the question is resolved or there is a change in state. The Interpreter also monitors CS to ensure that a person is not recorded as being in more than one location at a time.

A print-out of the model can be found in Appendix 8.2.

8.4.3 The Simulation

I ran the program for each question-order permutations and found that the outcomes predicted by the hand simulation were all obtained. In Appendix 8.3 I included a COGENT output for each condition. From the final contents of the 'Answers' object we can see that whenever the Apast\(^{21}\) (answer - Object1) or Apres (Object3) question was asked first, the Bpast answer (Object2) was lost. It was only when the Bpast question was asked first that the Bpast answer was available. However, now if the Apast question was asked next, the Apres answer was lost. This did not occur if the Apres question was second and the Apast third. In this condition, both the Bpast and Apres questions enter the system when their corresponding answers can be accessed in the ITP. In this condition then, there is no interference and all 3 question are answered correctly.

The final contents of the 'New Records' Object shows the records that resulted from the operation of the Interpreter. The are two relevant features to note with regard to the contents of this buffer. First, as implemented, the absence of a record in this buffer is directly linked to the pattern of interference. Second, the type of 'answer' record that is created is determined by the location of the answer to the question: If the answer was retrieved, a secondary record was created in addition to the primary record that provided the answer; if the answer was accessed in the ITP, then there was a single primary record that included the relevant event structure as well as the answer; finally, if the answer was accessed from the

\(^{21}\)Apast corresponds to PaPa (i.e. past truck's past state) in the simulation. Similarly, Apres = PaPr (past truck's present state) and Bpast = PrPa (present truck's past state).
CS, then the record contained only the answer to the question. Ideally, the record with a CS answer (i.e. Object3) should also contain relevant structures; the Interpreter should look in the CS and ITP for relevant structures (i.e. load(truck1, object3)) and incorporate them into this ‘answer’ record. However, in the simulation, which inputs the relevant structures into the system rather than create them, the structure associated with the CS answer was not yet in the system, and therefore it was not included. Furthermore, when it did enter the system it was overwritten as a result of the second question being asked. Consequently, there was no record of the loading of Object3, which again is undesirable. This can only be corrected when the parser’s integrating functions are implemented.

Overall, the simulation reproduced the outcomes that were predicted by the hand simulation and the theory. Now it was time to go back to the field and empirically test two of the more crucial question-order permutations. The first is the condition in which all answers are answered correctly and the second is one of the conditions in which the Apres question is asked first.

8.5 Truck Study - An Introduction to Experiment 2 (Truck2)

The following study tested two further question-order permutations. The first is the 6th question order permutation (Order6) in Table 8.1. In this condition it is predicted that children will answer all 3 questions correctly. The second question-order permutation is the 3rd permutation (Order3) in Table 8.1, in which Apres is the first question. In this order condition, it is predicted that the majority of children will provide wrong answers to the Bpast question, whereas the Apast and Apres questions will be answered correctly.

8.6 Method

Subjects

The subjects were 32 nursery school children including 17 girls and 15 boys and ranging in age from 3:4 to 4:10 (mean age - 4:3). The children were all English speaking monolinguals. Sixteen children were randomly assigned to each of the experimental conditions. There were 9 girls and 7 boys in Order3 condition (mean age = 4:4) and 8 girls and 8 boys in Order6 condition (mean age = 4:1). The children were recruited from Hallfield nursery in Bayswater and were of varying socio-economic backgrounds. Three additional children were excluded for responding with ‘I don’t know’ to all questions.
Design and Procedure

Design, materials and procedure were identical to those used in the first truck experiment, with two exceptions. First, since the previous truck experiment showed no effect of configuration, only one configuration was used in the truck2 experiment - configuration 4 in the truck1 experiment (Table 8.2):

<table>
<thead>
<tr>
<th>Configuration 4</th>
<th>Truck A Initial state</th>
<th>Truck A Final state</th>
<th>Truck B Initial state</th>
<th>Truck B Final state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furniture</td>
<td>Food</td>
<td>People</td>
<td>Boxes</td>
<td></td>
</tr>
</tbody>
</table>

Second, the order of questions was different:

Order3 condition
1. The truck that you carried, What is in it now? - truckA’s Present state - Apres.
2. The truck that you carried, what was in it? - truckA’s Past state - Apast.
3. The truck that you are carrying, what was in it? - truckB’s Past state - Bpast.

Order6 condition:
1. The truck that you are carrying, what was in it? - truckB’s Past state - Bpast.
2. The truck that you carried, What is in it now? - truckA’s Present state - Apres.
3. The truck that you carried, what was in it? - truckA’s Past state - Apast

8.7 Results and Discussion

The children’s responses to the test questions were categorised as either ‘correct’ or ‘incorrect’. Table 8.2 presents the frequencies of correct responses, broken down by question type and question order.

<table>
<thead>
<tr>
<th></th>
<th>Apast</th>
<th>Bpast</th>
<th>Apres</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order 3</td>
<td>11</td>
<td>0</td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>Order 6</td>
<td>13</td>
<td>11</td>
<td>13</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>11</td>
<td>22</td>
<td>57</td>
</tr>
</tbody>
</table>
Table 8.2 shows a similar pattern of variation in the number of correct responses in Order3 condition as that observed in Condition 1 in the first truck experiment. Similarly, the Apast question elicited the greatest number of correct responses and the Bpast question the least. A Cochran Q Test for related designs showed these differences to be significant ($Q = 18.38; df = 2; p < 0.001$). Unlike the previous experiment, this time an order effect seemed to have been present. Table 8.2 reveals that overall the Order6 condition produced a larger number of correct responses than the Order3 condition, which was mainly due the differences in the number of correct responses to the Bpast question. This difference in the total number of correct responses between the groups was significant ($X^2 = 7.49, df = 1, p < 0.025$). The effect of the order on the frequency of correct responses to the Bpast question in particular is clearly evident in Figure 8.3.

In both order conditions the majority of the children answered the Apast and the Apres question correctly. In contrast, responses to the 'B past' question were sensitive to order. In Order3 condition, when the Apres question was presented first, and was then followed by preceded by the Apast and the Bpast question (Apres-->Apast-->Bpast), all children gave the wrong answer to the Bpast question. However, in the Order6 condition, when the Bpast question was presented first and then Apres and Apast, most children were able to provide correct response to this question. The effect of the order on the frequency of correct responses to the Bpast question was significant ($X^2 = 16.76, df = 1, p < 0.001$).

The results supported the predictions. In Order3 condition, when the first question is answered from the CS, the Bpast information, which is in the ITP at that time, was lost. Since no retrieval was involved, the only reason for the loss of the Bpast information is the creation
of an 'answer' record in response to the first question. In Order6 condition, all questions were answered correctly because with this question-order both the Bpast and Apres questions entered the system when their corresponding answers could be accessed in the ITP; therefore, no interference was present and all three questions were answered correctly.
9. CONCLUSIONS

9.1 An Overview

In this thesis the Headed Records model was extended in a number of ways: the notion of a current state buffer has been introduced; the need for a separate on-line buffer, serving the interpreter, has been shown through a combination of experiment and simulation; certain conditions leading to the creation of records have been identified, and a number of factors concerning the limitations of 3- to 4-year-olds have been traced. I will first summarize the finding - both in relation to the theory and in relation to the child; I will then discuss the implication of these findings to present and future research.

9.2 Extensions to The Theory

9.2.1 Dual Buffer system

The need for a dual buffer system, the Current State Buffer and the Interpreter Buffer, has become apparent both theoretically and empirically. To start with, if existing records are used as the basis for interpretation, they must be made available to the interpretation processes. The use of records for interpretation was clear from both the 'Mickey' and the SB1 studies. In both studies, repetition of the event led to better performance. In the Mickey experiment (Chapter 5) the improvement was in terms of the quality and quantity of recall. In the SB1 experiment, the improvement (in the Bag condition) was evident in the successful resolution of a theory of mind problem which usually leads to failure. Repetition extends knowledge of event type (representational knowledge) by referring to records of similar previous experiences. This increases the parser's relative speed of processing and, in turn, leads to an increase in the amount of information that can be encoded, and to the degree of organisation that can be imposed. The improvement in the 'Mickey' and the SB1 studies thus indicates that in both cases the record(s) of the first event were used as the reference record(s) for the repetition of the event.

Given the need for a reference record there is the option of either using a copy operation or keeping a long term representation active in memory. Preference for the former
was motivated by two reasons: to avoid changes to long-term representations and to dissociate interpretation processes from search processes. Indeed, one of the Framework's kernel assumptions is that there are no changes to LTM representations. However, we know from previous work on misinformation that new experiences affect subsequent recall such that newly introduced material seems to penetrate recall of the original memory. The most common explanation for this phenomenon is one that involves changes to existing representations, although more recently Loftus (1982, 1989), the originator of this work and the associated explanation, has come to accept the possibility that new memories are created rather than old memories modified— an explanation which was empirically supported by Bekerian and Bowers (1983). It remains, however, that old and new information can be confused and therefore must be integrated at some point. The on-line buffer is the place in which old and new meet, and rather than new information penetrating old memories it is a case of old memories penetrating the new information (or the new records). The old memory or record provides the base for interpretation, the interpreter thus absorbs any information that is similar, incorporates completely new information, and replaces any old information that is conflicting. This leads to the general prediction that old conflicting information in the referent record will not be included as part of newly formed representation. This prediction was upheld in the lack of interference within the ‘event’ group in the ‘Mickey’ study.

Once the justification for copying records into a buffer was established, it would have been rational, within the context of the theory, to postulate an independent on-line buffer for this function which is dissociated from a typical limited capacity buffer, as it would have been reasonable to assume that a limited capacity buffer will be unable to maintain both (theoretically unlimited) record information and on-line information. I did not make this assumption originally. But then the data focused my attention. The selective loss of information in the Truck1 experiment could only be explained by assuming a dual buffer system (Section 7.6). The data from the SB2 experiment too could only be accounted for within a dual-buffer system (Section 6.10). The simulation and the 2nd truck experiment, now making specific predictions, then further supported this distinction.

9.2.2 Record creation

The main ideas confirmed by the findings in this thesis are that each experience leads to the creation of an independent set of records, and that questions, as well as actual experiences, lead to the creation of records.
First, the HR framework's assumption of unique representations for each experienced event, irrespective of the degree of similarity, was supported by the findings. The lack of interference in the 'event' group in the 'Mickey' study clearly indicated the availability of a discrete and 'uncontaminated' (by interfering information from the first event) representation of the second event. This finding is in direct contrast to previous accounts (i.e. the GER and schema confirmation/deployment) in which it is assumed that similar experiences are integrated into a single structure.

The second idea confirmed by the data is that questions lead to the creation of records. There are two kinds of outcome. First, these records can then potentially interfere with the retrieval of records of the primary experience. This was found in the 'interview' group's recall of the second 'Mickey' event where interference was found in access to the primary records of this second event by the secondary records of the previous interview. The alternative kind of outcome, found in the second truck experiment, was that the creation of the question records interfered directly with the creation of new primary records by causing material in the ITP Buffer to be deleted. This also suggested that questions have a priority.

Two of the main extensions to the theory were revealed as a result of younger children's restricted capacity. The question order-effect that directed my attention to the possible existence of a second on-line buffer, as well as to the role questions play in the creation of new primary records, would not have been present in a system of a less restricted capacity as that assumed in relation to older children and adults.

9.3 The Child's Development

9.3.1 Capacity

We know from the existing literature that the memory system of younger children is more restricted in terms of the amount of information it can temporarily store. Their overall processing, therefore, will naturally be more segmented and more selective. However, as I discussed in Chapter 4, it is not capacity alone that leads to attenuated recall.

First, capacity limitation will dictate more segmented processing and the subsequent creation of more records per event. Yet, it is the lack of chaining ability (i.e. the use of record information as the means of iteration of the retrieval cycle - c.f. Williams & Hollan, 1981) which will prevent an event from being accessed in full, and general development (i.e. linguistic and conceptual) which will determine whether sufficient descriptions are formed and
Conclusions

consequently whether the appropriate records are accessed. In terms of behaviour, this restriction will be expressed particularly as a failure to recall specific, unique events which, by virtue of being unique, are expected to be less well organised in memory. The ‘Mickey’ event demonstrated that when the need for chaining is bypassed by provision of specific cues, children can and do recall a novel event more completely - a finding which challenges the standard view that young children’s difficulty with specific events reflects a problem at encoding.

Second, restricted capacity will also impose more selective processing and will lead to greater loss of information. However, it is the parsing process that determines which information is selected and how it is segmented. The SB task showed that reduced computational demands overturned the typical loss of a false belief representation. In the Tube condition, the transfer operation provided distinct segmentation points for the parser to trigger the creation of a record which contained the crucial piece of information, and in the Bag2 condition the existence of a referent record focussed the parser on the relevant information and on the need for marking. And with regard to beliefs, the findings from this study strongly oppose the notion of a conceptual deficit as the cause for the younger child’s failure to recall a false belief advocated by ToM competence accounts.

The fact that under the appropriate experimental conditions both the above mentioned restrictions were overcome, supports my original argument that limitations in young children memory performance are mostly caused by performance rather than competence factors.

9.3.2 Marking of representations

The SB1 study revealed developmental differences in the ability to mark representations on-line (i.e. as they are formed), which, I suggest, are linked to developments in the parser’s organisational ability. Specifically, the ability to evaluate and assess the relevance of representations that exist in the on-line buffers (particularly outdated or seemingly redundant representations) in relation to a goal structure. The ‘double’, ‘reversed’ and ‘correct’ response groups may reflect different stages in the development of this ability. Initially, the parser does not evaluate such representations; it only incorporates immediately relevant representations into existing structures at the expense of destructive update (the ‘double’ group). Later, the parser gradually begins to evaluate those representations, but it does not do this efficiently; it does not immediately update the representations, but it still has
difficulties incorporating them into a single structure. In consequence, the resulting structure may be extended but it will be disorganised (this point was made in Chapter 6 when discussing the more variable nature of the improvement between conditions in the ‘reversed’ group). The parser then gradually becomes more efficient; marking the source of representations, for example, will make this process more efficient. The resulting structures will be both extended and better organized.

Note, however, that this is only a tentative suggestion. The trends in the data are not sufficiently strong to justify firm conclusions. This will require that the parser is implemented and additional tests are carried out.

9.4 Implications and Future Directions

Three general conclusions can be drawn on the basis of the findings in this thesis:
1. Limitations on children’s behaviour reflect performance rather than competence factors.
2. Two buffer stores, as opposed to a single, working memory, buffer, are involved in on-line processing.
3. The interaction between modelling, both theoretical and computational, and empirical work provides a strong basis for theory development.

9.4.1 Limitations on children’s behaviour

On the basis of the data from this thesis it can be concluded that restrictions on young children’s performance mostly reflect performance rather than competence limitations. This was true not only in relation to the child’s memory for specific events, but also in relation to the child’s theory of mind, or more precisely, her understanding of the concept of belief.

First, the data demonstrated that, contrary to common belief, young children’s difficulties in recalling specific events do not reflect a problem at encoding but rather a problem at retrieval, which can be, and was, overcome with the provision of specific cues. These data in conjunction with the intrusions data also reject the view that similar events are necessarily merged into a single schematised structure at the cost of specific detail. We saw that children were not only able to recall a complex event in full, but they were also able to differentiate between similar events as long as there was no interference from secondary (interview) records. Future work must now focus on how such similar, and independently encoded events are subsequently processed to produce a schematised structure.

Second, children’s inability to recall a false belief was shown to result from limitations in capacity which lead to loss of a crucial piece of information - and not with the understanding
of the concept of belief. The typical failure to recall false beliefs was overturned in the SB task by reducing the capacity demands imposed on the child in the original task. ToM competence accounts with their notion of a conceptual deficit, will find it hard to explain this finding without reorganising their theoretical models, to the extent that they exist, and redefining some of their basic assumptions. The Sally-Ann task is the next obvious step forward. Applying the same rational within a memory framework it is likely that young children’s success rates on the Sally-Ann task could be increased with the appropriate modifications and through repetition.

9.4.2 A dual-buffer system

The data from two independent experiments made a strong case for a dual buffer system. In Chapter 7 I have distinguished between these two on-line buffers in terms of the type of information that is stored by each, and loosely defined the functional differences between them on the basis of this distinction. To reiterate, I suggested that the CS may be viewed as a window to the world - storing perceptual information in a prepositional form; and the ITP as the window to the mind - holding internally generated representations as well as newly formed complex prepositional structures. This characterisation of the buffers is clearly too vague to suffice. Work should now proceed towards establishing a more theoretically precise definition of the role each buffer is playing in central processing, and a more sound differentiation of function. One possible route to take in this pursuit is to adopt neuropsychological paradigms and search for possible dissociation of function. For example, the model would predict a dissociation between short term storage of information (the CS) the creation of new (event) memories (ITP) and loss of long term representations (LTM). We already know that a dissociation exist between short term memory (the STM syndrome) and long term memories (retrograde amnesia). It is also known that some patients show an inability to learn new skills (anterograde amnesia). The question is how these deficits are related to the components defined within the HR model. For example, within the anterograde group is it possible to distinguish between patients who have difficulties creating new memories (parser) and those who find it difficult to acquire new skills (inferencer and problem solving) and those who are incapable of learning anything new at all (ITP)? The model would predict the existence of these sub-groups, but this remains to be seen.
9.4.3 The Combination of Modelling and Empirical work

In Chapter 1 I advocated the merging of modelling and empirical paradigms into a single research programme as a way of avoiding incommensurability and promoting scientific progress - I believe the thesis made this point. It made this point first, by demonstrating how a single solution - the model, when well specified, could be applied within different problem domains (event memory and theory of mind); and second, by showing how the use of different methodologies (developmental and computational) can lead to a better articulated, and possibly a more accurate solution.

The model I outlined in Chapter 3 was conceived within the HR framework, which was originally formulated to explain memory phenomenon in normal adults. Nevertheless, once this model was derived, it could then be used to account for event memory phenomenon in young children as well as in adults. Moreover, this very same model could also be applied within the theory of mind domain to explain young children's failure on false beliefs tasks, and to make predictions regarding their behaviour on similar tasks. Now, I am turning to neuropsychology as another possible area of application. And, as we saw in the previous section, the model is already suggesting a number of predictions with regard to the kinds of memory deficits that may be expected in amnesiac patients.

Exploring this neuropyschological path is advantageous for another reason - it introduces a new set of constrains to impose on the model, and this leads me to the second point: the use of different methodologies. Using different methodologies is likely to lead to better articulated solutions, because, and as I already discussed in Chapter 1, different methodologies impose different types of constrains. The work in this thesis demonstrated the advantages. The combination of modelling and developmental work (the former constraining the solution, i.e. the theory, and the latter constraining the problem domain, i.e. the memory system\(^{22}\)) produced the majority of the findings in this thesis and led to the formation of a well specified and falsifiable model. We started by reducing a framework into a model and saw what this model can tell us about the child. We then got to know what the child can tell us about this model. Thus, it was the young child's restricted capacity that suggested the existence of an additional on-line buffer, but at the same time it was the existence of the model that enabled the possibility of this explanation.

\(^{22}\) Brain injury will also constrain the problem domain, however, as the limitations imposed by injury would be different from those imposed by development, the implications to the model would be different as well.


References


Box (1953). Non-normality and tests on variance. *Biometrika, 40,* 318-335.


References


References


References


Journal of Developmental Psychology, 9, 159-171.


APPENDIX 5.1

The script for the ‘Mickey’ Event
The script for the ‘Mickey’ Event

20 red/blue balloons are to be left as a bunch in the lobby. The transfer (from staff-room to lobby) should take place during story time when the children are seated in the book corner. The door to the class-room should be closed during lunch. A note should be placed on the entrance door asking visitors not to come in.

When the children are sent to get their food and take their seats they will most probably notice the balloons and will make a remark on that. The reply should be: Oh yes there is a bunch of red balloons in the corner! I wonder who might they belong to and how they got here? Any other question or remarks made by the children should be met with: "I don't know we will have to wait and see"

As most of the children come to the end of their lunch (during dessert) a staff member should alert 'Mickey' in the staff-room. Mickey will wait for about 2 minutes and then will enter the classroom.

In the classroom
A knock on the door. Mickey enters the room

"Oh dear! Oh dear! I can't find them anywhere".
"Hello children I am Mickey and I have lost all my red balloons and I feel ever so sad about it. Pause.
"Did any of you children see my red balloons?"
The children might say something about the red balloons in the corner. e.g. "There the balloons are over there"
To that, Mickey should reply:

"Fancy that, these are my balloons, I wonder how they got there. Do you know why I am looking for these balloons?"

Children:  "No"
Mickey :  "Because I want to send them to Donald-Duck. Do you know why?
Children:  "No"
Mickey :  "Because Donald has a party every Friday, and this Friday I can't go to his party, so I want to send the red balloons instead, will you children help me send them?"

Children: reply "YES" or "NO"
Mickey :  "If you help me send the balloons to Donald I will have a surprise for you. Pause. Shall I tell you how you can help me?"

Children: reply "YES" or "NO"
Mickey :  "When you go to the bathroom to wash your hands, you must bring me one red balloon, and then you can have your surprise."

Mickey leaves the classroom and goes to the bathroom.

Each child is to be sent to the bathroom individually. A staff member should be standing with the balloons and helping each child to get a balloon. Then, send the child to the bathroom and ask him/her to wait until the previous child has come out.

In the Bathroom
Child enters.
Mickey: "Can you tell me your name"
Child replies
Mickey: "Well < >, could you take the clip off for me and let the air out"
Child lets the air out.
Mickey: "Good, now we can fit the balloon into the sack, "Could you put the balloon in the sack for me"
Child puts balloon in the sack
Mickey: "Well done, now you can go to the grown-ups bathroom and get your surprise."

_In the Grown-ups Bathroom_
Child enters
Exp.: "Hello < >, did you come for your surprise?"
Child replies
Exp.: "Can you unlock this box? the surprise is waiting for you in there."
Child unlocks the lock with a key, experimenter opens the box and gives < > a gold balloon; then asks them to go and stay in the quiet room.
APPENDIX 5.2

The Interview for the 'Mickey' Event
The Interview

(1) Can you remember what happened during lunchtime yesterday?
   Can you tell me all about it?
   (1a) Did anything special happen during lunch time yesterday?
   (1b) Did anyone special come to visit during lunch?
   (1c) Did Mickey Mouse come to visit you during lunch time?
(2) What else? ....
(3) Was Mickey Mouse looking for something?
   (3a) What was he looking for?
   (3b) Was he looking for something you can play with?
   (3c) Was he looking for balloons?
(4) What colour were the balloons?
   (4a) Were the balloons red/blue?
(5) What did he want to do with the balloons?
   (5a) Did he want to send the balloons to anybody?
   (5b) Who did he want to send the balloons to?
   (5c) Did he want to send the balloons to Donald duck?
(6) Why did he want to send the balloons to Donald?
   (6a) What was going to happen at Donald's?
   (6b) Did he want to send the balloons to Donald for his party?
(7) Did Mickey find his balloons?
(8) Where were the balloons?
   (8a) In which area of the class-room were the balloons?
   (8b) Were the balloons in the lobby area?
(9) What happened next?
(10) Did you have to take something to Mickey?
   (10a) Did you have to take a balloon to Mickey?
(11) How did you get the balloon?
   (11a) Did you have to get one balloon from the bunch?
   (11b) Did a grown-up help you?
   (11c) Which grown-up helped you?
   (11d) Was it Nasarine/Miriam
(12) What did you do with the balloon then?
   (12a) Did you take the balloon to the bathroom?
(13) What happened in the bathroom?
   (13a) Was there anybody in the bathroom?
   (13b) Who was in the bathroom?
   (13c) Was Mickey in the bathroom?
(14) What did you have to do in the bathroom?
   (14a) Did you have to do something with the balloon?
   (14b) Did you have to let the air out of the balloon?
(15) How did you let the air out?
   (15a) Did you have to take something off?
   (15b) Did you have to take the clips off?
(16) What did you do with the empty balloon?
   (16a) Did you have to put the balloon into something?
   (16b) Did you have to put the balloon in a sack/present box?
(17) Was it a special sack?
   (17a) Did it have anything on?
Did the sack have a picture on?
Who was on the picture?
Was it a Donald-Duck picture?
Where did you go after you'd been to the bathroom?
Did you go to the grown-ups toilet?
What happened in the grown-ups toilet?
Was there anybody in there?
Was I in the grown-ups toilet?
What did you have to do in the grown-ups toilet?
Did you have to open something?
Did you have to open a box?
How did you open the box?
Did you have to use something to open the box with?
Did you have to use a key?
What was in the box?
Was there something you can play with?
Was the surprise in the box?
What was it?
Was it a balloon/sticker?
What colour was it/What kind of sticker was it?
Was it a gold balloon/was it a Mickey Mouse sticker?
Where did you go then?
Did you go to the quiet room?
APPENDIX 7.1

The Story Associated with Each Configuration in the Truck Study
The Narrative for the Truck Event

Location1 - This is the Smith family (picture is shown) and they have a shop in another town. But not long ago they have bought this beautiful new shop and today they are moving their things to this new shop. The only problem is that they need a driver (point to the truck), they have a truck but they still need a driver because their first driver disappeared, so they want you to help them move? Will you do it, will you be the driver? ....

Configuration 1
...the first driver also made a complete mass of things, look he delivered the food first, but there is nowhere to put the food so we must take it back and bring in a few other things first.

Location2 - this is the shop that the Smiths people used to have, but they are leaving this shop today. Look, their first driver put these empty boxes in the truck, but it is no good to send empty boxes to the other shop we must use them for the food. (Exp2 and child unload the food from TA and the boxes from TB, food is put in the boxes). Lets put the smiths people on one truck (exp2 guiding reloading of TA) and the furniture on the other and send the furniture first so they can be arranged in the new shop, and smiths will arrive in the other truck to help with the furniture. Only then we can come back for the food.

Configuration 2
...the first driver also made a complete mass of things, look he delivered empty boxes, but there is no use in empty boxes, we have to take these boxes back and fill them with things. Location2 - this is the shop that the Smiths people used to have, but they are leaving this shop today. Look, their first driver just threw the food on the truck but we cannot carry it this way because everything will break. So lets take these boxes from this truck (TA) and use them for the food. (Unload boxes and food and put food in boxes). Now lets put the furniture on this truck (TA) so we can arrange the furniture in the shop before the food arrives, and send the Smiths people with this truck(TB) to the new shop so that they can clean it first of all.

Configuration 3
...the Smiths have just finished cleaning their new shop and they now want to go back to the old shop and start with the move. Location2 - this is the shop that the Smiths people used to have, but they are leaving this shop today. Look, their first driver was going to send the furniture first. Nevertheless, we need to send the boxes first to clear all the rubbish that they cleared from the new shop and then we can send the food. (Unload Smiths and boxes from the trucks and load the food on TA and the boxes on TB). Now you can carry the boxes.

Configuration 4
...the first driver also made a complete mass of things, he delivered the furniture from the old shop, but these furniture do not belong here, they are part of the old shop so we have to take them back. Location2 - this is the shop that the Smiths people used to have, but they are leaving this shop today. I see you brought back the furniture that belongs to this old shop, so lets put the furniture back in the old shop and help the Smiths get off the other truck so that they can arrange the furniture back in place (Unload furniture and the Smiths). Now lets put the food on this truck (TA), and put the boxes in this truck (TB) and take them to the new shop to clear up all the rubbish.
APPENDIX 8.1

COGENT Specifications for the Category Identification Demo
**Tutorial 3: Reading from Buffers**

A demonstration of buffers and properties related to storage

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**Category Memory**

Class: Buffer/Propositional

Properties:
- Initialise: Each Block
- Decay: Probabilistic
- Capacity: 1

Description: None

Initial Contents:
- Element: *Cat is a domestic animal*  
  category(cat, domestic_animal)
- Element: *Dog is a domestic animal*  
  category(dog, domestic_animal)
- Element: *Cow is a farm animal*  
  category(cow, farm_animal)
- Element: *Chicken is a farm animal*  
  category(chicken, farm_animal)
- Element: *Lion is a wild animal*  
  category(lion, wild_animal)
- Element: *Elephant is a wild animal*  
  category(elephant, wild_animal)
- Element: *Ant is an insect*  
  category(ant, insect)
- Element: *No comment*  
  category(cat, domestic_animal)
- Element: *Dog is a domestic animal*  
  category(dog, domestic_animal)
- Element: *Cow is a farm animal*  
  category(cow, farm_animal)
- Element: *Chicken is a farm animal*  
  category(chicken, farm_animal)
- Element: *Lion is a wild animal*  
  category(lion, wild_animal)
- Element: *Elephant is a wild animal*  
  category(elephant, wild_animal)

Duplicates: No

Decay Constant: 5

On Excess: Random

Access: FIFO

Limited Capacity: No
Element: Ant is an insect
category(ant, insect)

Current Contents:
0: category(ant, insect).
0: category(elephant, wild_animal).
0: category(lion, wild_animal).
0: category(chicken, farm_animal).
0: category(dog, domestic_animal).

Message Log: None

Output
The results of looking up our categories

File: Accumulate: Yes

Results:
trial(1, 1, 'Mon Dec 16 16:38:14 1996').
(2, domestic_animal).
(2, wild_animal).
(3, domestic_animal).

Message Log:
1: Look-up Category -> Output: domestic_animal
1: Look-up Category -> Output: wild_animal
2: Look-up Category -> Output: domestic_animal

Input

Class: Data/Source
Description: None
Initial Contents:
Input on cycle 1:
send dog to Look-up Category
send elephant to Look-up Category
Input on cycle 2: First animal is a cat
send cat to Look-up Category

Current Contents: None
Message Log:
1: Input -> Look-up Category: dog
1: Input -> Look-up Category: elephant
2: Input -> Look-up Category: cat

Look-up Category
When triggered by an animal name, find its category

Class: Process
Properties:
Firing Rate: 1.000000
Recurrent: No
Description: None

Contents:
Rule (unrefracted): Look up an animal's category
TRIGGER: Animal
IF: category(Animal, Type) is in Category Memory
THEN: send Type to Output

Message Log:
1: Input -> Look-up Category: dog
1: Input -> Look-up Category: elephant
1: Look-up Category -> Output: domestic_animal
1: Look-up Category -> Output: wild_animal
2: Input -> Look-up Category: cat
2: Look-up Category -> Output: domestic_animal
APPENDIX 8.2

COGENT Specifications for the HR Model
Record Creation #3

Class: Compound
Description: None

New Records

Class: Buffer/Propositional
Properties:
- Initialise: Each Trial
- Decay: None
- Capacity: 0
Description: None
Initial Contents: None
Current Contents:
22: record([load(child, object4, truck2, old_shop)]).
20: record([unload(child, object1, truck1, old_shop), carry(child, truck1), at(child, old_shop), object1]).
14: record([unload(child, object2, truck2, old_shop), object2]).
9: record([unload(child, object1, truck1, old_shop), carry(child, truck1), at(child, old_shop)]).
6: record([transport(child, truck1, new_shop, old_shop), at(child, new_shop)]).

Message Log:
5: Integrator -> New Records: add(record([transport(child, truck1, new_shop, old_shop), at(child, new_shop)]))
8: Integrator -> New Records: add(record([unload(child, object1, truck1, old_shop), carry(child, truck1), at(child, old_shop)]))
13: Integrator -> New Records: add(record([unload(child, object2, truck2, old_shop), object2]))
19: Integrator -> New Records: add(record([unload(child, object1, truck1, old_shop), carry(child, truck1), at(child, old_shop), object1]))
21: Integrator -> New Records: add(record([load(child, object4, truck2, old_shop)]))

Answers

Class: Data/Sink
Properties:
- File: data.current
- Accumulate: No
Description: None
Results: None
Message Log:
13: Integrator -> Answers: answer(object2)
17: Integrator -> Answers: retrieving a record
19: Integrator -> Answers: answer(object1)
24: Integrator -> Answers: no answer
Integrator

Class: Process
Properties:
  Firing Rate: 1.000000  Recurrent: No

Description:
This process looks in the ITP for an event schema and tries to bind any variables in that schema to objects in the current state.

Contents:

Rule (refracted): Things can only be in one place at a time
IF: at(X, Y) is in Current State
   at(X, Z) is in ITP
THEN: delete at(X, Z) from ITP

Rule (refracted): The location of the child gets transferred straight from CS to ITP
IF: at(child, Y) is in Current State
THEN: add at(child, Y) to ITP
   delete at(child, Y) from Current State

Rule (refracted): move current goal (carry) from CS to ITP
IF: carry(child, T) is in Current State
THEN: add carry(child, T) to ITP
   delete carry(child, T) from Current State

Rule (refracted): maintain goal in itp
IF: carry(child, T) is in ITP
   not at(child, oldShop) is in ITP
THEN: add carry(child, T) to ITP

Rule (refracted): Shunt questions in the current state straight through to ITP
IF: question(Z) is in Current State
THEN: add question(Z) to ITP
   delete question(Z) from Current State

Rule (refracted): Answer a clause of a question from CS
IF: question(X ^ [First|Rest]) is in ITP
   call look_in_cs(First)
THEN: delete question(X ^ [First|Rest]) from ITP
   add question(X ^ Rest) to ITP

Rule (refracted): Answer a clause of a question from ITP
IF: question(X ^ [First|Rest]) is in ITP
   not call look_in_itp(First)
   call look_in_itp(First)
THEN: delete question(X ^ [First|Rest]) from ITP
   add question(X ^ Rest) to ITP

Rule (refracted): Once all clauses been answered, make the answer explicit
IF: question(X ^ []) is in ITP
THEN: delete question(X ^ []) from ITP
   send answer(X) to Answers

Rule (refracted): Dispatch the record
IF: record(R) is in ITP
   not call retrieve_record(_) 
   not call wait
   not answering_question is in ITP
THEN: add record(R) to New Records
   delete record(_) from ITP

Rule (refracted): dispatch record 2
IF: record(R) is in ITP
   do_not_retrieve is in ITP
THEN: add record(R) to New Records
   delete record(R) from ITP

Rule (refracted): Look for a matching record and retrieve it
IF: call retrieve_record(R)
call match_record(R)
THEN: send 'retrieving a record' to Answers
   add record(R) to ITP

Rule (refracted): Set "no answers" flag
IF: not call match_record(R)
call retrieve_record(R)
THEN: add do_not_retrieve to ITP

Rule (refracted): Report no answers
IF: do_not_retrieve is in ITP
   not call match_record(R)
   question(X ^ [First|Rest]) is in ITP
THEN: send 'no answer' to Answers
   delete answering_question from ITP
Rule (refracted): If there is a complete structure then close a record
IF: 
call close_record
R is the list of all X such that X is in ITP
not X = carry(child, truck2)
THEN: add record(R) to ITP
add carry(child, truck2) to ITP
clear ITP

Rule (unrefracted): Rule
IF: 
call wait
THEN: add answering_question to ITP

Rule (unrefracted): dispatch record after an answer is provided
IF: 
calling_question is in ITP
THEN: add record(L) to New Records
clear ITP

Rule (refracted): dispatch record after an answer is provided
IF: 
question(X [ ]) is in ITP
not call answer_from_record(R, X)
R = question(X [ ])
THEN: add record(R) to New Records
clear ITP

Condition: answer_from_record/2: Condition
answer_from_record(R, X) :-
question(X [ ]) is in ITP
record(R) is in ITP
load(_, X, _, _) is a member of R
answer_from_record(R, X) :-
question(X [ ]) is in ITP
record(R) is in ITP
unload(_, X, _, _) is a member of R

Condition: wait/0:
wait :-
question(X [First|Rest]) is in ITP
call look_in_cs(First)
wait :-
question(X [First|Rest]) is in ITP
call look_in_itp(First)

Condition: close_record/1: Should we close a record?
close_record :-
unload(_, _, _, _) is in ITP
close_record :-
load(_, _, _, _) is in ITP
close_record :-
transport(_, _, _, _) is in ITP

Condition: opposite_truck/2: What’s the opposite truck?
opposite_truck(truck1, truck2).
opposite_truck(truck2, truck1).

Condition: retrieve_record/1:
retrieve_record(R) :-
question(X [First|Rest]) is in ITP
not call look_in_cs(First)
not call look_in_itp(First)
record(R) is in New Records

Condition: match_record/1:
match_record(R) :-
question(X [past(in(X, Y))]) is in ITP
record(R) is in New Records
unload(_, X, Y, _) is a member of R
match_record(R) :-
question(X [present(in(X, Y))]) is in ITP
record(R) is in New Records
load(_, X, Y, _) is a member of R
match_record(R) :-
question(X [past(in(X, Y))]) is in ITP
record(R) is in New Records
unload(_, X, Y, _) is a member of R
Y is in Current State

Condition: look_in_cs/1: Is the answer in CS?
look_in_cs(present(Z)) :-
Z is in ITP
look_in_cs(present(Z)) :-
Z is in Current State
look_in_cs(past(carry(child, TA))) :-
carry(child, TB) is in ITP
call opposite_truck(TA, TB)

Condition: look_in_itp/1: Is the answer in ITP?
look_in_itp(past(in(X, Y))) :-
    unload(_, X, Y, _) is in ITP

look_in_itp(present(in(X, Y))) :-
    load(_, X, Y, _) is in ITP

look_in_itp(past(in(X, Y))) :-
    record(R) is in ITP
    unload(_, X, Y, _) is a member of R

look_in_itp(present(in(X, Y))) :-
    Y is in Current State
    record(R) is in ITP
    unload(_, X, Y, _) is a member of R

Message Log:

1: Integrator -> ITP: add(at(child, new_shop))
2: Integrator -> Current State: del(at(child, new_shop))
3: Integrator -> ITP: add(carry(child, truck1))
4: Integrator -> Current State: del(carry(child, truck1))
5: Integrator -> ITP: add(record(transport(child, truck1, new_shop, old_shop), at(child, new_shop)))
6: Integrator -> ITP: add(carry(child, truck2))
7: Integrator -> ITP: clear
8: Integrator -> New Records: add(record([transport(child, truck1, new_shop, old_shop), at(child, new_shop)]))
9: Integrator -> ITP: del(record(_))
10: Integrator -> ITP: add(question(A ^ [present(carry(child, B)), past(in(A, B))]))
11: Integrator -> Current State: del(question(A ^ [present(carry(child, B)), past(in(A, B))]))
12: Integrator -> ITP: add(record([unload(child, object1, truck1, old_shop), carry(child, truck1), at(child, old_shop)]))
13: Integrator -> ITP: clear
14: Integrator -> ITP: add(question(A ^ [past(in(A, truck1))])
15: Integrator -> ITP: del(question(A ^ [past(carry(child, truck1)), past(in(A, truck1))])
16: Integrator -> Answers: retrieving a record
17: Integrator -> ITP: add(record([unload(child, object1, truck1, old_shop), carry(child, truck1), at(child, old_shop)]))
18: Integrator -> ITP: add(question(object1 ^ []))
19: Integrator -> ITP: del(question(object1 ^ []))
20: Integrator -> ITP: add(carry(child, truck2))
20: Integrator -> FTP: clear
21: Integrator -> FTP: add(question(A ^ \{past(carry(child, B)), present(in(A, B))\}))
21: Integrator -> Current State: del(question(A ^ \{past(carry(child, B)), present(in(A, B))\}))
21: Integrator -> New Records: add(record(\{load(child, object4, truck2, old_shop)\}))
21: Integrator -> FTP: del(record(_))
22: Integrator > ITP: add(question(A ^ \{present(in(A, truck 1))\}))
22: Integrator > ITP: del(question(A ^ \{past(carry(child, truck 1)), present(in(A, truck 1))\}))
22: Integrator > ITP: add(answering_question)
23: Integrator > ITP: add(do_not_retrieve)
23: Integrator > ITP: add(do_not_retrieve)
23: Integrator > ITP: add(do_not_retrieve)
23: Integrator > ITP: add(do_not_retrieve)
23: Integrator > ITP: add(do_not_retrieve)
24: Integrator -> Answers: no answer

LTM Recall

Class: Data/Source
Description: None
Initial Contents:
Input on cycle 1: Nothing
Input on cycle 2: Nothing
Input on cycle 3: Nothing
Input on cycle 4: Recall transport event
add transport(child, truck1, new_shop, old_shop) to ITP
Input on cycle 5: Nothing
Input on cycle 6: Nothing
Input on cycle 7: Recall unloading of truck 1
add unload(child, object1, truck1, old_shop) to ITP
Input on cycle 8: Nothing
Input on cycle 9: Nothing
Input on cycle 10: Recall unloading of truck 2
add unload(child, object2, truck2, old_shop) to ITP
Input on cycle 11: Nothing
Input on cycle 12: Nothing
Input on cycle 13: Nothing
Input on cycle 14: Nothing
Input on cycle 15: Recall loading of truck 1
add load(child, object3, truck1, old_shop) to ITP
Input on cycle 16: Nothing
Input on cycle 17: Nothing
Input on cycle 18: Nothing
Input on cycle 19: Nothing
Input on cycle 20: Recall loading of truck 2
add load(child, object4, truck2, old_shop) to ITP

Current Contents: None
Message Log:
4: LTM Recall -> ITP: add(transport(child, truck1, new_shop, old_shop))
7: LTM Recall -> ITP: add(unload(child, object1, truck1, old_shop))
10: LTM Recall -> ITP: add(unload(child, object2, truck2, old_shop))
15: LTM Recall -> ITP: add(load(child, object3, truck1, old_shop))
20: LTM Recall -> ITP: add(load(child, object4, truck2, old_shop))

ITP

Class: Buffer/Propositional
Properties:
Initialise: Each Trial
Decay: None
Capacity: 0
Description: None
Duplicates: No
Decay Constant: 4
On Excess: Random
Access: FIFO
Limited Capacity: No
Initial Contents: None

Current Contents:

24: do_not_retrieve.

23: question(A ^ [present(in(A, truck1))]).

21: carry(child, truck2).

Message Log:

1: Integrator -> ITP: add(at(child, new_shop))

4: LTM Recall -> ITP: add(transport(child, truck1, new_shop, old_shop))

4: Integrator -> ITP: add(carry(child, truck1))

4: Integrator -> ITP: add(record(transport(child, truck1, new_shop, old_shop), at(child, new_shop)))

4: Integrator -> ITP: add(carry(child, truck2))

4: Integrator -> ITP: clear

5: Integrator -> ITP: add(at(child, old_shop))

5: Integrator -> ITP: add(carry(child, truck2))

5: Integrator -> ITP: add(carry(child, truck1))

5: Integrator -> ITP: del(record(_))

7: LTM Recall -> ITP: add(unload(child, object1, truck1, old_shop))

7: Integrator -> ITP: add(record(unload(child, object1, truck1, old_shop), carry(child, truck1, at(child, old_shop))))

7: Integrator -> ITP: add(carry(child, truck2))

7: Integrator -> ITP: clear

8: Integrator -> ITP: del(record(_))

9: Integrator -> ITP: add(carry(child, truck2))

10: LTM Recall -> ITP: add(unload(child, object2, truck2, old_shop))

10: Integrator -> ITP: add(question(A ^ [present(carry(child, B)), past(in(A, B))]))

10: Integrator -> ITP: add(record(unload(child, object2, truck2, old_shop)))

10: Integrator -> ITP: add(carry(child, truck2))

10: Integrator -> ITP: clear

11: Integrator -> ITP: add(question(A ^ [past(in(A, truck2))]))

11: Integrator -> ITP: del(question(A ^ [present(carry(child, truck2)), past(in(A, truck2))]))

11: Integrator -> ITP: add(answering_question)

12: Integrator -> ITP: add(question(object2 ^ []))

12: Integrator -> ITP: del(question(object2 ^ [past(in(object2, truck2))]))

12: Integrator -> ITP: add(answering_question)

13: Integrator -> ITP: del(question(object2 ^ []))

13: Integrator -> ITP: clear

15: LTM Recall -> ITP: add(load(child, object3, truck1, old_shop))

15: Integrator -> ITP: add(question(A ^ [past(carry(child, B)), past(in(A, B))]))

15: Integrator -> ITP: add(record(load(child, object3, truck1, old_shop)))

15: Integrator -> ITP: add(carry(child, truck2))

15: Integrator -> ITP: clear

16: Integrator -> ITP: add(question(A ^ [past(in(A, truck1))]))

16: Integrator -> ITP: del(question(A ^ [past(carry(child, truck1)), past(in(A, truck1))]))

16: Integrator -> ITP: add(answering_question)

17: Integrator -> ITP: add(record(unload(child, object1, truck1, old_shop), carry(child, truck1, at(child, old_shop))))

18: Integrator -> ITP: add(question(object1 ^ []))

18: Integrator -> ITP: del(question(object1 ^ [past(in(object1, truck1))]))

18: Integrator -> ITP: add(answering_question)

19: Integrator -> ITP: del(question(object1 ^ []))

19: Integrator -> ITP: clear

20: LTM Recall -> ITP: add(load(child, object4, truck2, old_shop))

20: Integrator -> ITP: add(record(load(child, object4, truck2, old_shop)))

20: Integrator -> ITP: add(carry(child, truck2))

20: Integrator -> ITP: clear

21: Integrator -> ITP: add(question(A ^ [past(carry(child, B)), present(in(A, B))]))

21: Integrator -> ITP: del(record(_))

22: Integrator -> ITP: add(question(A ^ [present(in(A, truck1))]))

22: Integrator -> ITP: del(question(A ^ [past(carry(child, truck1)), present(in(A, truck1))]))

22: Integrator -> ITP: add(answering_question)

23: Integrator -> ITP: add(do_not_retrieve)

23: Integrator -> ITP: add(do_not_retrieve)

23: Integrator -> ITP: add(do_not_retrieve)

23: Integrator -> ITP: add(do_not_retrieve)

24: Integrator -> ITP: del(answering_question)
Attention Outputs

Initial Contents:

- **Input on cycle 1**: Child and experimenter are at the new shop
  - add at(child, new_shop) to Current State
  - add at(exp1, new_shop) to Current State

- **Input on cycle 2**: add picture(smiths) to Current State
  - add in(picture, new_shop) to Current State
  - add in(object1, truck1) to Current State
  - add at(truck1, new_shop) to Current State

- **Input on cycle 3**: add child(driver) to Current State

- **Input on cycle 4**: add carry(child, truck1) to Current State

- **Input on cycle 5**: add at(child, old_shop) to Current State
  - add at(exp2, old_shop) to Current State

- **Input on cycle 6**: add at(truck2, old_shop) to Current State
  - add in(object2, truck2) to Current State
  - add in(object3 + object4, old_shop) to Current State

- **Input on cycle 7**: add in(object2, old_shop) to Current State
  - add in(object1, old_shop) to Current State
  - add at(truck1, old_shop) to Current State

- **Input on cycle 8**: add in(object4, truck2) to Current State
  - add in(object3, truck1) to Current State

- **Input on cycle 9**: add carry(child, truck2) to Current State

- **Input on cycle 10**: Question: PrPa
  - add question(X [present(carry(child, Y)), past(in(X, Y))]) to Current State

- **Input on cycle 11**: add in(object4, truck2) to Current State
  - add at(exp2, new_shop) to Current State

- **Input on cycle 12**: Nothing

- **Input on cycle 13**: Nothing

- **Input on cycle 14**: Nothing

- **Input on cycle 15**: Question: PaPa
  - add question(X [past(carry(child, Y)), past(in(X, Y))]) to Current State

- **Input on cycle 16**: Nothing

- **Input on cycle 17**: Nothing

- **Input on cycle 18**: Nothing

- **Input on cycle 19**: Nothing

- **Input on cycle 20**: Nothing

- **Input on cycle 21**: Question: PaPr
  - add question(X [past(carry(child, Y)), present(in(X, Y))]) to Current State

Current Contents: None

Message Log:

1: Attention Outputs -> Current State: add(at(child, new_shop))
2: Attention Outputs -> Current State: add(at(exp1, new_shop))
3: Attention Outputs -> Current State: add(picture(smiths))
4: Attention Outputs -> Current State: add(in(picture, new_shop))
5: Attention Outputs -> Current State: add(at(truck1, new_shop))
6: Attention Outputs -> Current State: add(child(driver))
7: Attention Outputs -> Current State: add(at(child, old_shop))
8: Attention Outputs -> Current State: add(in(object1, truck1))
9: Attention Outputs -> Current State: add(addin(truck1, new_shop))
10: Attention Outputs -> Current State: add(at(child, old_shop))
11: Attention Outputs -> Current State: add(in(exp2, old_shop))
12: Attention Outputs -> Current State: add(in(object2, truck2))
13: Attention Outputs -> Current State: add(in(object3 + object4, old_shop))
14: Attention Outputs -> Current State: add(in(object2, old_shop))
15: Attention Outputs -> Current State: add(at(child, new_shop))
16: Attention Outputs -> Current State: add(at(truck1, new_shop))
17: Attention Outputs -> Current State: add(in(object3 + object4, old_shop))
Current State

Class: Buffer/Propositional
Properties:
- Initialise: Each Trial
- Duplicates: No
- Decay Constant: 20
Description: None
Initial Contents: None
Current Contents:
11: at(exp2, new_shop).
11: in(object4, truck1).

Message Log:
1: Attention Outputs -> Current State: add(at(child, new_shop))
1: Attention Outputs -> Current State: add(at(exp1, new_shop))
1: Integrator -> Current State: del(at(child, new_shop))
2: Attention Outputs -> Current State: add(picture(smiths))
2: Attention Outputs -> Current State: add(in(picture, new_shop))
2: Attention Outputs -> Current State: add(at(truck1, new_shop))
2: Attention Outputs -> Current State: add(child(driver))
4: Attention Outputs -> Current State: add(carry(child, truck1))
4: Integrator -> Current State: del(carry(child, truck1))
5: Attention Outputs -> Current State: add(at(child, old_shop))
5: Attention Outputs -> Current State: add(at(exp2, old_shop))
5: Integrator -> Current State: del(at(child, old_shop))
6: Attention Outputs -> Current State: add(at(truck2, old_shop))
6: Attention Outputs -> Current State: add(in(object2, truck2))
6: Attention Outputs -> Current State: add(in(object3 + object4, old_shop))
7: Attention Outputs -> Current State: add(in(object1, old_shop))
7: Attention Outputs -> Current State: add(at(truck1, old_shop))
8: Attention Outputs -> Current State: add(in(object4, truck2))
8: Attention Outputs -> Current State: add(in(object3, truck1))
9: Attention Outputs -> Current State: add(carry(child, truck2))
9: Integrator -> Current State: del(carry(child, truck2))
10: Attention Outputs -> Current State: add(question(A ^ [present(carry(child, B)), past(in(A, B))]))
10: Integrator -> Current State: del(question(A ^ [present(carry(child, B)), past(in(A, B))]))
11: Attention Outputs -> Current State: add(in(object4, truck2))
11: Attention Outputs -> Current State: add(at(exp2, new_shop))
15: Attention Outputs -> Current State: add(question(A ^ [past(carry(child, B)), past(in(A, B))]))
15: Integrator -> Current State: del(question(A ^ [past(carry(child, B)), past(in(A, B))]))
21: Attention Outputs -> Current State: add(question(A ^ [past(carry(child, B)), present(in(A, B))]))
21: Integrator -> Current State: del(question(A ^ [past(carry(child, B)), present(in(A, B))]))
APPENDIX 8.3

The Simulation Results for all Question Order Permutations
Record Creation #3

Class: Compound
Description: None

Attention Outputs

Class: Data/Source
Description: None
Initial Contents:
Input on cycle 1: Child and experimenter are at the new shop
  add at(child, new_shop) to Current State
  add at(exp1, new_shop) to Current State
Input on cycle 2:
  add picture(smiths) to Current State
  add in(picture, new_shop) to Current State
  add in(object1, truck1) to Current State
Input on cycle 3:
  add child(driver) to Current State
Input on cycle 4:
  add carry(child, truck1) to Current State
Input on cycle 5:
  add at(child, old_shop) to Current State
  add at(exp2, old_shop) to Current State
Input on cycle 6:
  add load(child, object1, truck1, old_shop) to ITP
Input on cycle 7:
  Recall unloading of truck 1
  add unload(child, object1, truck1, old_shop) to ITP
Input on cycle 8:
  Recall loading of truck 1
  add load(child, object1, truck1, old_shop) to ITP
Input on cycle 9:
  Recall loading of truck 2
  add load(child, object2, truck2, old Shop) to ITP
Input on cycle 10:
  Recall unloading of truck 2
  add unload(child, object2, truck2, old_shop) to ITP
Input on cycle 11:
  add question(X * [present(carry(child, Y)), past(in(X, Y))]) to Current State
Input on cycle 12: Nothing
Input on cycle 13: Nothing
Input on cycle 14: Nothing
Input on cycle 15: Question: PrPr
  add question(X * [past(carry(child, Y)), past(in(X, Y))]) to Current State
Input on cycle 16: Nothing
Input on cycle 17: Nothing
Input on cycle 18: Nothing
Input on cycle 19: Nothing
Input on cycle 20: Nothing
Input on cycle 21: Question: PaPr
  add question(X * [past(carry(child, Y)), present(in(X, Y))]) to Current State
Current Contents: None

LTM Recall

Class: Data/Source
Description: None
Initial Contents:
Input on cycle 1: Nothing
Input on cycle 2: Nothing
Input on cycle 3: Nothing
Input on cycle 4: Recall transport event
  add transport(child, truck1, new_shop, old_shop) to ITP
Input on cycle 5: Nothing
Input on cycle 6: Nothing
Input on cycle 7: Recall unloading of truck 1
  add unload(child, object1, truck1, old_shop) to ITP
Input on cycle 8: Nothing
Input on cycle 9: Nothing
Input on cycle 10: Recall unloading of truck 2
  add unload(child, object2, truck2, old_shop) to ITP
Input on cycle 11: Nothing
Input on cycle 12: Nothing
Input on cycle 13: Nothing
Input on cycle 14: Nothing
Input on cycle 15: Recall loading of truck 1
  add load(child, object1, truck1, old Shop) to ITP
Input on cycle 16: Nothing
Input on cycle 17: Nothing
Input on cycle 18: Nothing
Input on cycle 19: Nothing
Input on cycle 20: Recall loading of truck 2
  add load(child, object2, truck2, old_shop) to ITP
Current Contents: None

Current State

Class: Buffer/Limited Capacity
Properties:
  Initialise: Each Trial
  Capacity: 3
  Duplicates: No
  Access: FIFO
  Decay Constant: 20
  Decay: None
  On Excess: Oldest
Description: None
Initial Contents: None
Current Contents:
11: at(exp2,new_shop).
11: in(object4,iruck2).

ITP
Class: Buffer/Unlimited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Access: FIFO
Decay: None
Decay Constant: 4
Description: None
Initial Contents: None
Current Contents: <EMPTY>

Answers
Class: Data/Sink
Properties:
File: Accumulate: No
Description: None
Results:
trial(1,'Thu Dec 19 09:58:18 1996').
(13, retrieving a record).
(15, answer(object1)).
(19, no answer).
(24, retrieving a record).
(26, answer(object3)).

New Records
Class: Buffer/Unlimited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Access: FIFO
Decay: None
Decay Constant: 20
Description: None
Initial Contents: None
Current Contents:
26: record([load(child,object3,truck1,old_shop),object3]).
22: record([load(child,object4,truck2,old_shop),do_not_retrieve,question(A, [past(in(A,truck2))])).
19: record([load(child,object2,truck1,old_shop)]).
15: record([unload(child,object1,truck1,old_shop),carry(child,truck1),at(child,old_shop),object1]).
9: record([unload(child,object1,truck1,old_shop),carry(child,truck1),at(child,old_shop)]).
6: record([transport(child,truck1,new_shop,old_shop),at(child,new_shop)]).

Integrator
Class: Process
Properties:
Recursive: No
Description:
This process looks in the ITP for an event schema and tries to bind any variables
in that schema to objects in the current state.
Contents:
Rule (refracted): Things can only be in one place at a time
IF:
- at(X, Y) is in Current State
- at(X, Z) is in ITP
THEN: delete at(X, Z) from ITP
Rule (unrefracted): dispatch record after an answer is provided

IF: answering_question is in ITP
- call answer_from_record(R, X)
L results from appending R to [X]
THEN: add record(L) to New Records
clear ITP

Rule (refracted): dispatch record after an answer is provided

IF: question(X & [ ]) is in ITP
not call answer_from_record(R, X)
R = question(X & [ ])
THEN: add record(R) to New Records
clear ITP

Condition: answer_from_record/2: Condition
answer_from_record(R, X) :-
question(X & [ ]) is in ITP
record(R) is in FTP
load(_, X, _, _) is a member of R
answer_from_record(R, X) :-
question(X & [ ]) is in ITP
record(R) is in FTP
unload(_, X, _, _) is a member of R

Condition: wait/0:
wait :-
question(X & [First|Rest]) is in ITP
- call look_in_cs(First)
wait :-
question(X & [First|Rest]) is in ITP
- call look_in_itp(First)
Condition: close_record/1: Should we close a record?
close_record :-
load(_, X, _, _) is in ITP
close_record :-
unload(_, X, _, _) is in ITP
close_record :-
transport(_, X, _, _) is in ITP

Condition: opposite_truck/2: What's the opposite truck?
opposite_truck(truck1, truck2).
opposite_truck(truck2, truck1).
Condition: retrieve_record/1:
retrieve_record(R) :-
question(X & [First|Rest]) is in ITP
not call look_in_cs(First)
not call look_in_itp(First)
record(R) is in New Records
Condition: match_record/1:
match_record(R) :-
question(X & [past(in(X, Y))]) is in ITP
record(R) is in New Records
unload(_, X, Y, _) is a member of R
match_record(R) :-
question(X & [present(in(X, Y))]) is in ITP
record(R) is in New Records
load(_, X, Y, _) is a member of R
match_record(R) :-
question(X & [past(in(X, Y))]) is in ITP
record(R) is in New Records
unload(_, X, Y, _) is a member of R
Y is in Current State
Condition: look_in_cs/1: Is the answer in CS?
look_in_cs(present(Z)) :-
Z is in ITP
look_in_cs(present(Z)) :-
Z is in Current State
look_in_cs(past(carry(child, TA))) :-
carry(child, TB) is in ITP
call opposite_truck(TA, TB)
Condition: look_in_itp/1: Is the answer in ITP?
look_in_itp(present(in(X, Y))) :-
unload(_, X, Y, _) is in ITP
look_in_itp(present(in(X, Y))) :-
load(_, X, Y, _) is in ITP
look_in_itp(present(in(X, Y))) :-
record(R) is in FTP
load(_, X, Y, _) is a member of R
look_in_itp(present(in(X, Y))) :-
record(R) is in FTP
load(_, X, Y, _) is a member of R
Attention Outputs

Class: Compound
Description: None

Current State

Input on cycle 1: Child and experimenter are at the new shop
add at(child, new_shop) to Current State
add at(expl, new_shop) to Current State

Input on cycle 2:
add picture(smith) to Current State
add in(picture, new_shop) to Current State
add in(object1, truck1) to Current State
add at(truck1, new_shop) to Current State

Input on cycle 3:
add child(driver) to Current State

Input on cycle 4:
add carry(child, truck1) to Current State

Input on cycle 5:
add at(truck2, old_shop) to Current State
add in(object2, truck2) to Current State
add in(object3 + object4, old_shop) to Current State

Input on cycle 6:
add in(object2, old_shop) to Current State
add in(object3, truck2) to Current State

Input on cycle 7:
add in(object4, truck2) to Current State
add at(object4, truck2) to Current State

Input on cycle 8:
add carry(child, truck2) to Current State

Input on cycle 9: Question: PaPa
add question(X * [past(carry(child, Y)), past(in(X, Y))]) to Current State

Input on cycle 10: Question: PaPr
add question(X * [past(carry(child, Y)), present(in(X, Y))]) to Current State

Current Contents: None

LTM Recall

Class: Data/Source
Description: None

Initial Contents:
Input on cycle 1: Nothing
Input on cycle 2: Nothing
Input on cycle 3: Nothing

Input on cycle 4: Recall transport event
add transport(child, truck1, new_shop, old_shop) to ITP

Input on cycle 5: Nothing
Input on cycle 6: Nothing
Input on cycle 7: Recall unloading of truck 1
add unload(child, object1, truck1, old_shop) to ITP

Input on cycle 8: Nothing
Input on cycle 9: Nothing
Input on cycle 10: Recall unloading of truck 2
add unload(child, object2, truck2, old_shop) to ITP

Input on cycle 11: Nothing
Input on cycle 12: Nothing
Input on cycle 13: Nothing
Input on cycle 14: Nothing

Input on cycle 15: Recall loading of truck 1
add load(child, object3, truck1, old_shop) to ITP

Input on cycle 16: Nothing
Input on cycle 17: Nothing
Input on cycle 18: Nothing
Input on cycle 19: Nothing

Input on cycle 20: Recall loading of truck 2
add load(child, object4, truck2, old_shop) to ITP

Current Contents: None

Current State

Class: Buffer/Limited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Capacity: 3
Access: FIFO
Decay Constant: 20
On Excess: Oldest
Decay: None
Description: None
Initial Contents: None
Current Contents:
11: at(exp2,new_shop).
11: in(object4, truck2).

ITP
Class: Buffer/Unlimited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Access: FIFO
Decay Constant: 4
Dependency: None
Description: None
Initial Contents: None
Current Contents:
24: do_not_retrieve.
23: question(A '[past(in(A, truck2))]).
21: carry(child, truck2).

Answers
Class: Data/Sink
Properties:
File: Accumulate: No
Description: None
Results:
trial(1, 1, 'This Dec 19 10:01:09 1996').
(13, retrieving a record).
(15, answer(object1)).
(19, answer(object3)).
(25, no answer).

New Records
Class: Buffer/Unlimited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Access: FIFO
Decay Constant: 20
Dependency: None
Description: None
Initial Contents: None
Current Contents:
22: record([load(child, object4, truck2, old_shop)]).
19: record([look(child, object3, truck1, old_shop), object3]).
15: record([unload(child, object1, truck1, old_shop), carry(child, truck1, at(child, old_shop), object1)]).
9: record([unload(child, object1, truck1, old_shop), carry(child, truck1, at(child, old_shop))]).
6: record([transport(child, truck1, new_shop, old_shop), at(child, new_shop)]).

Integrator
Class: Process
Properties:
Recursive: No
Description: This process looks in the ITP for an event schema and tries to bind any variables in that schema to objects in the current state.

Contents:
Rule (refracted): Things can only be in one place at a time
IF: at(X, Y) is in Current State
THEN: delete at(X, Z) from ITP

Rule (refracted): The location of the child gets transferred straight from CS to ITP
IF: at(child, Y) is in Current State
THEN: add at(child, Y) to ITP
delete at(child, Y) from Current State

Rule (refracted): move current goal (carry) from CS to ITP
IF: carry(child, T) is in Current State
THEN: add carry(child, T) to ITP
delete carry(child, T) from Current State

Rule (refracted): maintain goal in iip
IF: carry(child, T) is in ITP
THEN: add carry(child, T) to ITP
delete carry(child, T) from Current State

Rule (refracted): Shunt questions in the current state straight through to ITP
IF: question(Z) is in Current State
THEN: add question(Z) to ITP
delete question(Z) from Current State

Rule (refracted): Answer a clause of a question from CS
IF: question(X * [First|Rest]) is in ITP
THEN: delete question(X * [First|Rest]) from ITP

Rule (refracted): Dispatch the record
IF: record(R) is in ITP
THEN: add record(R) to New Records
delete record(_) from FTP

Rule (refracted): dispatch record 2
IF: record(R) is in ITP
do_not_retrieve is in FTP
THEN: add record(R) to New Records
delete record(R) from FTP

Rule (refracted): Look for a matching record and retrieve it
IF: call match_record(R)
call match_record(R)
THEN: send 'retrieving a record' to Answers
add record(R) to FTP

Rule (refracted): Set 'no answers' flag
IF: do_not_retrieve is in FTP
THEN: add do_not_retrieve to FTP

Rule (refracted): Report no answers
IF: do_not_retrieve is in FTP
THEN: add no answer to Answers

Rule (refracted): If there is a complete structure then close a record
IF: call close_record
R is the list of all X such that X is in ITP
THEN: add record(R) to FTP
add carry(child, truck2) to FTP

Rule (refracted): Rule
IF: call wait
THEN: add answering_question to FTP
Rule (unrefracted): dispatch record after an answer is provided
IF: answering_question is in ITP
   call answer_from_record(R, X)
L results from appending R to [X]
THEN: add record(L) to New Records
   clear ITP

Rule (refracted): dispatch record after an answer is provided
IF: question(X ^ []) is in ITP
   not call answer_from_record(R, X)
   R = question(X ^ [])
THEN: add record(R) to New Records
   clear ITP

Condition: answer_from_record/2: Condition
Condition: wait/0:
Condition: close_record/l: Should we close a record?
Condition: opposite_truck/2: What's the opposite truck?
Condition: retrieve_record/1:
Condition: match_record/1:
Condition: look_in_cs/1: Is the answer in CS?
Condition: look_in_ftp/1: Is the answer in FTP?
Record Creation #3

Class: Compound
Description: None

Attention Outputs

Current State

Integrator

ITP

New Records

Class: Data/Source
Description: None

Initial Contents:

Input on cycle 1: Child and experimenter are at the new shop
add at(child, new_shop) to Current State
add at(exp1, new_shop) to Current State

Input on cycle 2:
add in(object, new_shop) to Current State
add in(object1, truck1) to Current State
add at(truck1, new_shop) to Current State

Input on cycle 3:
add at(child, old_shop) to Current State

Input on cycle 4:
add carry(child, truck1) to Current State

Input on cycle 5:
add at(child, old_shop) to Current State
add at(exp2, old_shop) to Current State

Input on cycle 6:
add at(object1, truck2) to Current State
add in(object1, truck2) to Current State
add in(object1 + object4, old_shop) to Current State

Input on cycle 7:
add in(object1, old_shop) to Current State
add in(object1, old_shop) to Current State
add at(truck1, old_shop) to Current State

Input on cycle 8:
add in(object1, truck1) to Current State

Input on cycle 9:
add in(object1, truck1) to Current State

Input on cycle 10:
add carry(child, truck1) to Current State

Input on cycle 11: Question: PaPr
add question(X * [past(carry(child, Y)), present(in(X, Y))]) to Current State

Input on cycle 12: Nothing

Input on cycle 13: Nothing

Input on cycle 14: Nothing

Input on cycle 15: Question: PaPr
add question(X * [past(carry(child, Y)), present(in(X, Y))]) to Current State

Input on cycle 16: Nothing

Input on cycle 17: Nothing

Input on cycle 18: Nothing

Input on cycle 19: Nothing

Input on cycle 20: Nothing

Input on cycle 21: Question: PaPr
add question(X * [past(carry(child, Y)), present(in(X, Y))]) to Current State

Current Contents: None

LTM Recall

Class: Data/Source
Description: None

Initial Contents:

Input on cycle 1: Nothing

Input on cycle 2: Nothing

Input on cycle 3: Nothing

Input on cycle 4: Recall transport event
add transport(child, truck1, new_shop, old_shop) to ITP

Input on cycle 5: Nothing

Input on cycle 6: Nothing

Input on cycle 7: Recall unloading of truck 1
add unload(child, object1, truck1, old_shop) to ITP

Input on cycle 8: Nothing

Input on cycle 9: Nothing

Input on cycle 10: Recall unloading of truck 2
add unload(child, object2, truck2, old_shop) to ITP

Input on cycle 11: Nothing

Input on cycle 12: Nothing

Input on cycle 13: Nothing

Input on cycle 14: Nothing

Input on cycle 15: Recall loading of truck 1
add load(child, object1, truck1, old_shop) to ITP

Input on cycle 16: Nothing

Input on cycle 17: Nothing

Input on cycle 18: Nothing

Input on cycle 19: Nothing

Input on cycle 20: Recall loading of truck 2
add load(child, object4, truck2, old_shop) to ITP

Current Contents: None

Current State

Class: Buffer/Limited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Decay Constant: 20
Description: None

Capacity: 3
On Excess: Oldest
Access: FIFO
Decay: None
Initial Contents: None
Current Contents:
11: at(exp2,new_shop).
11: in(object4,truck2).

Class: Buffer/Unlimited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Decay: None
Decay Constant: 4
Description: None
Current Contents: None

ITP

Rule (refracted): The location of the child gets transferred straight from CS to ITP
IF: at(child, Y) is in Current State
THEN: add at(child, Y) to ITP
delete at(child, Y) from Current State

Rule (refracted): move current goal (carry) from CS to ITP
IF: carry(child, T) is in Current State
THEN: add carry(child, T) to ITP
delete carry(child, T) from Current State

Rule (refracted): maintain goal in ITP
IF: carry(child, T) is in ITP
not at(child, old_shop) is in ITP
THEN: add carry(child, T) to ITP

Rule (refracted): SHunt questions in the current state straight through to ITP
IF: question(Z) is in Current State
THEN: add question(Z) to ITP
delete question(Z) from Current State

Rule (refracted): Answer a clause of a question from CS
IF: question(X * [First|Rest]) is in ITP
call look_in_cs(First)
THEN: delete question(X * [First|Rest]) from ITP
add question(X * Rest) to ITP

Rule (refracted): Answer a clause of a question from ITP
IF: question(X * [First|Rest]) is in ITP
not call look_in_cs(First)
call look_in_ftp(First)
THEN: delete question(X * [First|Rest]) from ITP
add question(X * Rest) to ITP

Rule (refracted): Once all clauses been answered, make the answer explicit
IF: question( X * [J]) is in ITP
THEN: delete question( X * [J]) from ITP
send answer( X) to Answers

Rule (refracted): Dispatch the record
IF: record(R) is in ITP
not call retrieve_record(_) not answering_question is in FTP
THEN: add record(R) to New Records
delete record(_) from FTP

Rule (refracted): Look for a matching record and retrieve it
IF: call retrieve_record(R)
call match_record(R)
THEN: send 'retrieving a record' to Answers
add record(R) to FTP

Rule (refracted): Set 'no answers' flag
IF: not call match_record(R)
call retrieve_record(R)
THEN: add do_not_retrieve to FTP

Rule (refracted): Report no answers
IF: do_not_retrieve is in ITP
not call match_record(R)
question(X * [First|Rest]) is in ITP
THEN: send 'no answer' to Answers
delete answering_question from FTP

Rule (refracted): If there is a complete structure then close a record
IF: call close_record
R is the list of all X such that X is in ITP
not X = carry(child, truck2)
THEN: add record(R) to ITP
add carry(child, truck2) to ITP
clear ITP

Rule (unrefracted): Rule
IF: call wait
THEN: add answering_question to FTP

Answers

Class: Data/Sink
Properties:
File: None
Description: None
Results:
trial(1,"Thu Dec 19 10:06:44 1996").
(14,answer(object3)).
(13,answer(object1))
(25,no answer).

New Records

Class: Buffer/Unlimited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Decay: None
Decay Constant: 20
Description: None
Current Contents: None

Integrator

Rule (refracted): Things can only be in one place at a time
IF: at(X, Y) is in Current State
THEN: delete at(X, Y) from FTP

Class: Process
Properties:
Recursive: No
Description: This process looks in the FTP for an event schema and tries to bind any variables in that schema to objects in the current state.

Contents:
Rule (refracted): Things can only be in one place at a time
IF: at(X, Y) is in Current State
THEN: delete at(X, Z) from FTP
Rule (unrefracted): dispatch record after an answer is provided
IF: answering_question is in ITP
    call answer_from_record(R, X)
    L results from appending R to [X]
THEN: add record(L) to New Records
       clear ITP

Rule (refracted): dispatch record after an answer is provided
IF: question(X^*) is in ITP
    not call answer_from_record(R, X)
    R = question(X^*)
THEN: add record(R) to New Records
       clear ITP

Condition: answer_from_record/2: Condition
Condition: wait/0;
Condition: close_record/1: Should we close a record?
Condition: opposite_truck/2: What's the opposite truck?
Condition: retrieve_record/1;
Condition: match_record/1:
Condition: look_in_cs/1: Is the answer in CS?
Condition: look_in_itp/1: Is the answer in ITP?
Record Creation #3

Class: Compound
Description: None

Attention Outputs

Current State

Input on cycle 11:
add in(object4, truck2) to Current State
add at(exp2, new_shop) to Current State
Input on cycle 12: Nothing
Input on cycle 13: Nothing
Input on cycle 14: Nothing
Input on cycle 15: Question: PrPa
add question(X * [past(carry(child, Y)), list(in(X, Y))]) to Current State
Input on cycle 16: Nothing
Input on cycle 17: Nothing
Input on cycle 18: Nothing
Input on cycle 19: Nothing
Input on cycle 20: Nothing
Input on cycle 21: Question: PaPa
add question(X * [past(carry(child, Y)), list(in(X, Y))]) to Current State

Current Contents: None

LTM Recall

Class: Data/Source
Description: None
Initial Contents:
Input on cycle 1: Nothing
Input on cycle 2: Nothing
Input on cycle 3: Nothing
Input on cycle 4: Nothing
Input on cycle 5: Nothing
Input on cycle 6: Nothing
Input on cycle 7: Nothing
Input on cycle 8: Nothing
Input on cycle 9: Nothing
Input on cycle 10: Nothing
Input on cycle 11: Nothing
Input on cycle 12: Nothing
Input on cycle 13: Nothing
Input on cycle 14: Nothing
Input on cycle 15: Nothing
Input on cycle 16: Nothing
Input on cycle 17: Nothing
Input on cycle 18: Nothing
Current Contents: None

Buffer/Limited Capacity

Class: Buffer/Limited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Decay Constant: 20
Description: None
Capacity: 3
Access: FIFO
On Excess: Oldest
Decay: None

Current State

Input on cycle 1:
add at(child, new_shop) to Current State
add at(exp1, new_shop) to Current State
Input on cycle 2:
add at(child, new_shop) to Current State
add at(exp2, new_shop) to Current State
Input on cycle 3:
add at(truck1, new_shop) to Current State
Input on cycle 4:
add at(truck1, old_shop) to Current State
Input on cycle 5:
add at(child, old_shop) to Current State
Input on cycle 6:
add at(child, old_shop) to Current State
Input on cycle 7:
add at(child, old_shop) to Current State
Input on cycle 8:
add at(child, old_shop) to Current State
Input on cycle 9:
add at(child, old_shop) to Current State
Input on cycle 10:
add at(child, old_shop) to Current State
Input on cycle 11:
add at(child, old_shop) to Current State
Input on cycle 12:
add at(child, old_shop) to Current State
Input on cycle 13:
add at(child, old_shop) to Current State
Input on cycle 14:
add at(child, old_shop) to Current State
Input on cycle 15:
add at(child, old_shop) to Current State
Input on cycle 16:
add at(child, old_shop) to Current State
Input on cycle 17:
add at(child, old_shop) to Current State
Input on cycle 18:
add at(child, old_shop) to Current State
Input on cycle 19:
add at(child, old_shop) to Current State
Input on cycle 20:
add at(child, old_shop) to Current State
Input on cycle 21:
add at(child, old_shop) to Current State

Current Contents: None
Initial Contents: None
Current Contents:
11: in(exp2, new_shop).
11: in(object4, truck2).

ITP

Class: Buffer/Unlimited Capacity
Properties:
  Initial: Each Trial
  Decay: None
Description: None
Initial Contents: None
Current Contents:
<EMPTY>

Answers

Class: Data/Sink
Properties:
  File: Accumulate: No
Description: None
Results:
  trial(1, 1,'Thu Dec 19 10:08:13 1996').
  (14, answer(object3)).
  (19, no answer).
  (24, retrieving a record).
  (26, answer(object)).

New Records

Class: Buffer/Unlimited Capacity
Properties:
  Initial: Each Trial
  Decay: None
Description: None
Initial Contents: None
Current Contents:
26: record([unload(child, object1, truck1, old_shop), carry(child, truck1), at(child, old_shop), object1]).
22: record([load(child, object4, truck2, old_shop), do_not_retrieve, question(A^[past(in(A, truck2))])].
19: record([load(child, object3, truck1, old_shop)]).
14: record(question(object3^[1])).
9: record([unload(child, object1, truck1, old_shop), carry(child, truck1), at(child, old_shop)]).
6: record([transport(child, truck1, new_shop, old_shop), at(child, new_shop)]).

Integrator

Class: Process
Properties:
  Recursive: No
Description:
  This process looks in the ITP for an event schema and tries to bind any variables in that schema to objects in the current state.

Contents:
Rule (refracted): Things can only be in one place at a time
  IF: at(X, Y) is in Current State
  THEN: delete at(X, Y) from ITP
Rule (refracted): move current goal (carry) from CS to ITP
  IF: carry(child, T) is in Current State
  THEN: add carry(child, T) to ITP
  delete carry(child, T) from Current State
Rule (refracted): maintain goal in is
  IF: carry(child, T) is in ITP
  THEN: add carry(child, T) to ITP
  delete carry(child, T) from Current State
Rule (refracted): Shunt questions in the current state straight through to ITP
  IF: question(Z) is in Current State
  THEN: add question(Z) to ITP
  delete question(Z) from Current State
Rule (refracted): Answer a clause of a question from CS
  IF: question(X^[First|Rest]) is in ITP
  THEN: add question(X^[First|Rest]) to ITP
Rule (refracted): Dispatch the record
  IF: record(R) is in FTP
  THEN: add record(R) to New Records
  delete record(R) from FTP
Rule (refracted): Look for a matching record and retrieve it
  IF: call retrieve_record(R)
call match_record(R)
  THEN: send 'retrieving a record' to Answers
  add record(R) to FTP
Rule (refracted): Report no answers
  IF: do_not_retrieve is in FTP
  THEN: add do_not_retrieve to FTP
Rule (unrefracted): Rule
  IF: call wait
  THEN: add answering_question to FTP

IF: at(child, Y) is in Current State
THEN: add at(child, Y) to ITP
delete at(child, Y) from Current State
Rule (refracted): move current goal (carry) from CS to ITP
IF: carry(child, T) is in Current State
THEN: add carry(child, T) to ITP
delete carry(child, T) from Current State
Rule (refracted): maintain goal in is
IF: carry(child, T) is in ITP
THEN: add carry(child, T) to ITP
not at(child, old_shop) is in ITP
THEN: add carry(child, T) to ITP
Rule (refracted): Shunt questions in the current state straight through to ITP
IF: question(Z) is in Current State
THEN: add question(Z) to ITP
not at(child, old_shop) is in ITP
THEN: add question(Z) to ITP
Rule (refracted): Answer a clause of a question from CS
IF: question(X^[First|Rest]) is in ITP
not call look_in_cs(First)
call look_in_fd(First)
THEN: add question(X^[First|Rest]) to ITP
Rule (refracted): Dispatch the record
IF: record(R) is in FTP
not call retrieve_record(R)
call wait
 THEN: add record(R) to FTP
delete record(R) from FTP
Rule (refracted): Look for a matching record and retrieve it
IF: call retrieve_record(R)
call match_record(R)
THEN: send 'retrieving a record' to Answers
add record(R) to FTP
Rule (refracted): Report no answers
IF: do_not_retrieve is in FTP
THEN: add do_not_retrieve to FTP
Rule (refracted): If there is a complete structure then close a record
IF: close_record
R is the list of all X such that X is in FTP
THEN: add record(R) to FTP
Rule (unrefracted): Rule
IF: call wait
THEN: add answering_question to FTP
Record Creation #3

New Records

Class: Buffer/Unlimited Capacity
Properties:
  Initialise: Each Trial
  Duplicates: No
  Decay: None
  Decay Constant: 20
  Access: FIFO
Description: None

Current Contents:
22: record([load(child,object4,nuck2,old_shop)]).
20: record([unload(child,object1,truck1,old_shop),carry(child,truck1),at(child,old_shop),object1]).
14: record([unload(child,object2,truck2,old_shop),object2]).
9: record([unload(child,object1,truck1,old_shop),carry(child,truck1),at(child,old_shop)]).
6: record([transport(child,truck1,new_shop,old_shop),at(child,new_shop)]).

Answers

Class: Data/Sink
Properties:
  File: None
  Accumulate: No
Description: None

Results:
trial(1, 1, 'Tue Nov 5 17:47:55 1996').
(14,answer(object1)).
(18,retrieving a record).
(20,answer(object1)).
(23,no answer).

Integrator

Class: Process
Properties:
  Recursive: No
Description: This process looks in the ITP for an event schema and tries to bind any variables in that schema to objects in the current state.
Rule (unrefracted): dispatch record after an answer is provided
IF: answering_question is in ITP
THEN: add record(R) to New Records

clear ITP

Rule (refracted): dispatch record after an answer is provided
IF: question(X \[)) is in ITP
THEN: add record(R) to New Records

clear ITP

Condition: answer_from_record/2:
answer_from_record(R, X) :-
question(X \]) is in ITP
record(R) is in ITP
loadL . X, is a member of R

Condition: wait/0:
wait :-
question(X \[FirslRest\]) is in ITP
call look_in_cs(First)
wait :-
questionfX \(FirstlRest\) is in ITP
call look_in_itp(First)

Condition: close_record/I:
Should we close a record?
close_record :-
unloadL . _. _. _) is in ITP

close_record :-
loadL . _. _. _) is in ITP

close_record :-
transportL . J i s i n  ITP

Condition: opposite_truck/2:
What's the opposite truck?
opposite_truck(truckI, truck2).
opposite_lruck(truck2, truckl).

Condition: retrieve_record/I:
retrieve_record(R) :-
questionfX \[FirstlRest\]) is in ITP
not call look_in_cs(First)
not call look_in_itp(First)
record(R) is in New Records

Condition: match_record/I:
match_record(R) :-
question(X \[past(in(X, Y))\]) is in ITP
record(R) is in New Records
unloadL . X, Y, _) is a member of R

match_record(R) :-
questionfX \[present(in(X, Y))\]) is in ITP
record(R) is in New Records
loadL . X, Y, _) is a member of R

match_record(R) :-
questionfX \(past(in(X, Y))\) is in ITP
record(R) is in New Records
unloadL . X, Y, _) is a member of R

Y is in Current State

Condition: look_in_cs/2: Is the answer in CS?
look_in_cs(present(Z)) :-
Z is in ITP
look_in_cs(past(carry(child, TA ))) :-
carry(child, TB ) is in ITP
call opposite_truck(TA, TB)

Condition: look_in_itp/2: Is the answer in ITP?
look_in_itp(present(X, Y)) :-
Y is in Current State
look_in_itp(past(in(X, Y))) :-
loadL . X, Y, _) is in ITP

look_in_itp(past(in(X, Y))) :-
loadL . X, Y, _) is in ITP

look_in_itp(present(X, Y)) :-
record(R) is in ITP
unloadL . X, Y, _) is a member of R

look_in_itp(present(X, Y)) :-
record(R) is in ITP
loadL . X, Y, _) is a member of R
Input on cycle 4:
add carry(child, truck1) to Current State

Input on cycle 5:
add at(child, old_shop) to Current State
add at(exp2, old_shop) to Current State

Input on cycle 6:
add at(truck2, old_shop) to Current State
add at(exp2, truck2) to Current State
add in(object3 + object4, old_shop) to Current State

Input on cycle 7:
add at(object2, old_shop) to Current State
add at(object1, old_shop) to Current State

Input on cycle 8:
add at(object4, truck2) to Current State
add at(object3, truck1) to Current State

Input on cycle 9:
add carry(child, truck2) to Current State

Input on cycle 10:
Question: PaPa
add question(X \* lpast(carry(child, Y)), past(in(X, Y))) to Current State

Input on cycle 11:
add at(object4, truck2) to Current State
add at(exp2, new_shop) to Current State

Input on cycle 12: Nothing

Input on cycle 13: Nothing

Input on cycle 14: Nothing

Input on cycle 15: Question: PrPa
add question(X \* (past(carry(child, Y)), past(in(X, Y)))) to Current State

Input on cycle 16: Nothing

Input on cycle 17: Nothing

Input on cycle 18: Nothing

Input on cycle 19: Nothing

Input on cycle 20: Nothing

Input on cycle 21: Question: PaPr
add question(X \* (past(carry(child, Y)), present(in(X, Y)))) to Current State

Current Contents: None

Class: Buffer/Limited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Decay Constant: 20
Description: None
Initial Contents: None
Current Contents:
11: at(exp2, new_shop).
11: in(object4, truck2).

Current State

Class: Buffer/Limited Capacity
Properties:
Capacity: 3
On Excess: Oldest
Decay: None

Access: FIFO
Record Creation #3

Class: Compound
Description: None

Attention
Outputs

Class: Data/Source
Description: None

Initial Contents:
Input on cycle 1: Child and experimenter are at the new shop
add at(child, new_shop) to Current State
add at(exp2, new_shop) to Current State

Input on cycle 2:
add at(exp1, new_shop) to Current State
add at(truck1, new_shop) to Current State
add at(truck2, old_shop) to Current State

Input on cycle 3:
add at(child, driver) to Current State

Input on cycle 4:
add at(child, truck1) to Current State

Input on cycle 5:
add at(child, old_shop) to Current State
add at(exp2, old_shop) to Current State

Input on cycle 6:
add at(child, old_shop) to Current State
add at(object1, old_shop) to Current State
add at(object2, truck2) to Current State

Input on cycle 7:
add at(object2, old_shop) to Current State
add at(object1, old_shop) to Current State
add at(truck1, old_shop) to Current State

Input on cycle 8:
add at(object3, truck2) to Current State
add at(object4, truck2) to Current State

Input on cycle 9:
add carry(child, truck2) to Current State

Input on cycle 10: Question: PrPa
add question(X ^ (past(carry(child, Y)), present(in(X, Y)))) to Current State

Input on cycle 11:
add at(object4, truck2) to Current State
add at(exp2, new_shop) to Current State

Input on cycle 12: Nothing

Input on cycle 13: Nothing

Input on cycle 14: Nothing

Input on cycle 15: Question: PrPa
add question(X ^ (past(carry(child, Y)), present(in(X, Y)))) to Current State

Input on cycle 16: Nothing

Input on cycle 17: Nothing

Input on cycle 18: Nothing

Input on cycle 19: Nothing

Input on cycle 20: Nothing

Input on cycle 21: Question: PrPa
add question(X ^ (past(carry(child, Y)), present(in(X, Y)))) to Current State

Current Contents: None

LTM Recall

Class: Data/Source
Description: None

Initial Contents:
Input on cycle 1: Nothing
Input on cycle 2: Nothing
Input on cycle 3: Nothing

Input on cycle 4: Recall transport event
add transport(child, truck1, new_shop, old_shop) to ITP

Input on cycle 5: Nothing

Input on cycle 6: Nothing

Input on cycle 7: Recall unloading of truck 1
add unload(child, object1, truck1, old_shop) to ITP

Input on cycle 8: Nothing

Input on cycle 9: Nothing

Input on cycle 10: Recall unloading of truck 2
add unload(child, object2, truck2, old_shop) to ITP

Input on cycle 11: Nothing

Input on cycle 12: Nothing

Input on cycle 13: Nothing

Input on cycle 14: Nothing

Input on cycle 15: Recall loading of truck 1
add load(child, object3, truck1, old_shop) to ITP

Input on cycle 16: Nothing

Input on cycle 17: Nothing

Input on cycle 18: Nothing

Input on cycle 19: Nothing

Input on cycle 20: Recall loading of truck 2
add load(child, object4, truck2, old_shop) to ITP

Current Contents: None

Current State

Class: Buffer/Limited Capacity
Properties:
Initialise: Each Trial
Duplicates: No
Decay Constant: 20
Description: None

Capacity: 3
Access: FIFO
On Excess: Oldest
Decay: None
ITP

Class: Buffer/Unlimited Capacity
Properties:
Initialise: Each Trial  Duplicates: No  Access: FIFO  Decay: None  Decay Constant: 4
Description: None
Current Contents: <EMPTY>

Answers
Class: Data/Sink
Properties:
Initialise: Each Trial  Duplicates: No  Access: FIFO  File: Accumulate: No
Description: None
Results:
trial(1, 1, 'Thu Dec 19 10:09:33 1996').
(19,answer(object3)).
(24,retrieving a record).
(28,answer(object1)).

New Records
Class: Buffer/Unlimited Capacity
Properties:
Initialise: Each Trial  Duplicates: No  Access: FIFO  Decay: None  Decay Constant: 20
Description: None
Current Contents: None

Integrator
Class: Process
Properties:
Initialise: Each Trial  Duplicates: No  Access: FIFO  File: Accumulate: No
Description: None
Contents:
Rule (refracted): Things can only be in one place at a time
IF: at(X, Y) is in Current State
at(X, Z) is in ITP
THEN: delete at(X, Y) from ITP
Rule (refracted): The location of the child gets transferred straight from CS to ITP
IF: at(child, Y) is in Current State
THEN: add at(child, Y) to ITP
delete at(child, Y) from Current State
Rule (refracted): move current goal (carry) from CS to ITP
IF: carry(child, T) is in ITP
THEN: add carry(child, T) to ITP
delete carry(child, T) from Current State
Rule (refracted): maintain goal in ITP
IF: carry(child, T) is in ITP
THEN: add carry(child, T) to ITP
not at(child, old_shop) is in ITP
Rule (refracted): Shunt questions in the current state straight through to ITP
IF: question(Z) is in Current State
THEN: add question(Z) to ITP
delete question(Z) from Current State
Rule (refracted): Answer a clause of a question from CS
IF: question(X * [First|Rest]) is in ITP
call look_in_cs(First)
THEN: delete question(X * [First|Rest]) from ITP
add question(X * Rest) to ITP
Rule (refracted): Answer a clause of a question from ITP
IF: question(X * [First|Rest]) is in ITP
THEN: add question(X * [First|Rest]) to ITP
call look_in_ip(First)
delete question(X * [First|Rest]) from ITP
add question(X * Rest) to ITP
Rule (refracted): Dispatch the record
IF: record(R) is in ITP
THEN: add record(R) to New Records
delete record(_) from ITP
Rule (refracted): dispatch record 2
IF: record(R) is in ITP
do not retrieve is in ITP
THEN: add record(R) to New Records
delete record(_) from ITP
Rule (refracted): Look for a matching record and retrieve it
IF: call retrieve_record(R)
call match_record(R)
THEN: send 'retrieving a record' to Answers
add record(R) to ITP
Rule (refracted): Set 'no answers' flag
IF: not call match_record(R)
call retrieve_record(R)
THEN: add do_not_retrieve to ITP
Rule (refracted): Report no answers
IF: do_not_retrieve is in ITP
THEN: send 'no answer' to Answers
delete answering_question from ITP
Rule (refracted): If there is a complete structure then close a record
IF: call close_record
R is the list of all X such that X is in ITP
not X = carry(child, truck2)
THEN: add record(R) to ITP
add carry(child, truck2) to ITP
clear ITP
Rule (unrefracted): Rule
IF: call wait
THEN: add answering, question to ITP
Rule (unrefracted): dispatch record after an answer is provided
IF: answering_question is in ITP
call answer_from_record(R, X)
L results from appending R to [X]
THEN: add record(L) to New Records
clear ITP

Rule (refracted): dispatch record after an answer is provided
IF: question(X + []) is in ITP
not call answer_from_record(R, X)
R = question(X + [])
THEN: add record(R) to New Records
clear ITP

Condition: answer_from_record/2: Condition
Condition: wait/0:
Condition: close_record/1: Should we close a record?
Condition: opposite_truck/2: What's the opposite truck?
Condition: retrieve_record/1:
Condition: match_record/1:
Condition: look_in_cs/1: Is the answer in CS?
Condition: look_in_itp/1: Is the answer in ITP?