Memory For Time

Shashi Mittal, Sumeet Agarwal
Junior Undergraduate Students
Department of Computer Science and Engineering
Indian Institute of Technology
Kanpur, India - 208016

{mshashi,sagarwal}@iitk.ac.in

November 18, 2004

Abstract

In this paper, we present the various facets of memory for time, its observed properties, and the various models that have been devised to explain them. In particular, the Perturbation Model and the Inferential Model of memory are discussed in detail, since these two have been the most influential models for explaining the observed properties of memory for time. We also present the known facts about Autobiographical Memory and the Self Memory System.

1 Introduction

Memory for time has been one of the most active areas of research in Cognitive Psychology. Experimental studies on memory for recording events in temporal sequence show some very interesting and intriguing properties. These properties are presented in the second section. A number of models have been proposed for temporal memory. However, only two of them have been significantly successful in explaining the observed properties. These two models, namely the Perturbation Model and the Inferential Model, have been discussed in the next two sections. Then we present the known facts about Autobiographical Memory (i.e. memory for events occurring in one's own lifetime). In the end, we present the current status of research in this field, and what still remains to be explored.

2 Observed Properties of Memory for Time

Several robust properties of temporal memory have been uncovered by experiments over the past four decades. Any viable model of memory must explain these if it is to be taken seriously. The main experimentally observed properties of memory for time are enumerated as follows:

2.1 Primacy and Recency Effects

This well-known property of serial-order recall is observed with regard to temporal information as well. Subjects show better time judgment for items/events at the beginning and end of a sequence, and relatively poorer judgment for mid-sequence events. This behaviour is observed not only for items presented during experimental studies, but also for actual autobiographical events. For example, Hintzman, Block and Summers [7] performed a study where they presented two lists of 40 words each to the subjects. At testing time, the subjects were given a target word and asked to place it in the correct third of one of the lists. It was found that judgments were most accurate for words from the first third of list 1 and the last third of list 2; while they were least accurate for words from the middle thirds of both lists. Friedman [6] cites several other studies which clearly establish these effects as a general property of human memory.

2.2 Forward and Backward Telescoping

Forward telescoping refers to the tendency to judge events as having occurred more recently than their actual time of occurrence. This is a fairly common observation among people, and the likelihood and magnitude of telescoping increase as events get older. For example, an experiment was conducted by Thompson et al. [15] where subjects were asked to keep diaries of events for 12 weeks. At test, they were given events from their diaries at random and asked to date them. The subjects showed a considerable tendency to telescope events forward in time. Backward telescoping is also seen, where people judge events as having occurred earlier than the actual time. However, this phenomenon is much less common.

2.3 Better Ordering of Events with Longer Intervals Between them

A commonly observed fact is that it is easier to relatively order two events when they are separated by a greater temporal interval. This seems to be a fairly natural and intuitive property of our memory. For example, Tzeng and Cotton [16] conducted an experiment where they presented a list of 50 words at a rate of 2 seconds per word. At test, the subjects were given several pairs of words and for each pair, they were asked which one had occurred earlier in the presented list. It was found that for pairs separated by 9 or fewer words, accuracy was at about guessing levels (50%), but for pairs separated by 30 or more words, the subjects were correct around 80% of the time. This clearly demonstrated the interval effect.

2.4 Distinctive Time Scales

An intriguing but well-verified property of memory for time is the independence of our judgments on different time scales. Many times subjects report an accurate time on a fine scale (like hour of the day), but are inaccurate on a gross scale (like month of the year). For example, Friedman and Wilkins [3] asked subjects to give the date and time of ten major public events that had occurred from 6 months to 20 years before the experiment. They found that accuracy on different time scales was apparently uncorrelated. Later, Friedman [4] conducted another study where he asked people to give the date and time of an earthquake that had occurred 9 months earlier. He found that while people were off by about two months on an average in the date judgment, they could recall the time of day to within an hour. A reason for this might have been that the earthquake occurred around lunchtime, which served as a reference point. Hintzman et al. [7] found that in multiple list recall experiments, sometimes an item was recalled on the wrong list but at the correct position; another example of being more accurate on a finer scale. These results clearly show that we somehow make independent judgments of time on different temporal scales.

2.5 Boundary Effects

There seem to be certain boundary points within each time scale. Temporal judgments are more accurate for events lying at or near these points. For instance, Saturday and Sunday are boundary points on the day of week scale, while noon and midnight are boundaries on the hour of day scale. Experimentally, it has been found that subjects show greater accuracy at boundary points. For example, Shannon [14] conducted a study where he asked people to name the day of the week as quickly as they could. He found that the quickest responses were for Saturday and Sunday, and the slowest were for Wednesday. These effects are also culture-specific. Christians responded quickest on Sundays, while Jews did so on Saturdays; these being their respective Sabbath days.

3 Models Proposed

Several models have been proposed to try and explain memory for time. However, most of them don't work: they fail to explain one or more of the observed properties mentioned above. Friedman [6] classified these theories into three major categories: Distance, Location and Relative times. This classification is shown in Figure 1.

In the next few sections, we will discuss each of these models briefly, outlining their basic premises, pros and cons.

4 Distance Models

These models depend on processes that are correlated with the passage of time. These processes occur in between the times of encoding and retrieval, thus introducing a notion of 'distance' of memories, which can be used to used to judge their time of occurrence.

Model	Category	Idea
Strength	Distance	Trace Strength
Chronological Organization	Distance	Positions in memory
Contextual Overlap	Distance	Shared context
Time Tagging	Location	Time stamps
Perturbation	Location	Associated Control Elements
Reconstruction	Location	Associated Context, Knowledge
Associative Chaining	Relative times	Links between events (TODAM)
Order Code	Relative times	Pointers linking events

Figure 1: Eight theories of memory for time, classified into three broad categories. Adapted from Friedman [6].

4.1 Strength Theory

This theory says that each memory trace has a strength, which decreases with the passage of time. The decrease in strength may be due to decay or interference. The hypothesis is that the recency of a memory is judged by its strength, i.e., the stronger a memory trace, the more recent we think it is. This seems to be reasonable, as recent memories certainly do tend to be more vivid than old ones. The model explains the recency effect well, but does not account for the primacy effect. Another problem is that according to this model, memorable events should be judged as being more recent than they actually are, since their traces are stronger than average. Experimentally, it has been found that this is not the case. In fact, the more memorable an event is, the more accurately it seems to be dated. For example, Friedman [5] talks of some experiments where subjects were given a list of words, some of which they were specifically asked to remember. It was expected that at recall time, these words would be better recalled, as their traces would be stronger. This was indeed the case. However, the positions of these words in the list were judged more accurately than others, rather than their being telescoped forward. So, memorability and time judgment are apparently not based on the same information. Given these problems, plus the fact that it also doesn't account for independence of scales, the strength theory is not really viable as a general model of memory for time.

4.2 Chronological Organization Theory

According to this theory, events are stored in our memory in their order of occurrence. This means that as newer events come in, older ones recede, or go farther away, in some sense. Murdock [11] used the analogy of packages on a conveyor belt to describe this model: older memories are constantly moving further away as new ones keep coming in. The 'nearby' memories can be clearly seen and easily distinguished, while the older ones are blurry and merging into one another. Like other distance models, this one accounts for recency, but not for primacy. There are also other problems with this view. For example, Wagenaar [17] conducted a study where he, daily over a 6-year period, recorded one or two events he had experienced that day in a diary. For each event, he recorded four things: *what* it was, *who* it involved, *where* it happened and *when* in the day it took place. Later, he would give himself one of these cues and try to recall the others. On 157 occasions, he had recorded two events in a day, and when one of these came up at test, the card told him it was a double, and he would try to recall the other event of that day. He found that he could recall it on only 22 occasions. Not only that, for 20 of these 22 cases, the two events were clearly related by their location as well. So he concluded that contiguity in time is almost useless as a cue for retrieving memories. This obviously goes against the chronological organization model. With this model also not having an explanation for phenomena like independent time scales, it is naturally not taken very seriously.

4.3 Contextual Overlap Theory

This model hypothesizes that contextual components are associated with stimuli when they are encoded. These components may be, for example, environmental conditions or motivational states. Furthermore, these components change with time. So, the amount of contextual overlap between two memories might be used to judge their temporal separation. For example, if I'm a college student, then memories of college will have greater contextual overlap with my current context than memories of school. So the college memories will be judged to be more recent. But context can also change in a cyclic fashion. During summer, will memories from last summer seem more recent than memories from the intervening winter? Generally, no. This fact, plus the usual failure to explain primacy and scale effects, limit the utility of this theory.

5 Location Theories

These theories rely on information that is stored at the time of encoding, and retrieved later. This information establishes some 'location' for each memory, which gives the time of occurrence of that event. There are three prominent theories in this category. Two of these, perturbation and reconstruction, have been the two most successful models in terms of explaining the experimentally observed properties of memory for time. These two will be looked at in considerable detail. But first, we'll briefly talk about the simplest location theory: time-tagging.

5.1 Time-Tagging Theory

This theory simply asserts that temporal information is directly stored along with each event at the time of encoding, in the form of a time stamp. If we want to know when a given event occurred, we merely have to look at the associated time stamp. Since the nature of the information represented by the time stamp is not clearly specified, this is not a very coherent theory. If we think of the information as being directly the time of occurrence, then clearly the problem arises that we very rarely recall the exact (or even near-exact) time of occurrence of an event. For example, in Wagenaar's [17] study, he found that when he tried to recall the other cues from the *when* cue associated with an event, he generally couldn't do so. Also, given any one of the other cues, the *when* cue was the most difficult to retrieve. He concluded that timing information was almost useless in helping to remember other facets of an event. The inability to recall the correct time in most of the cases clearly goes against the notion of an explicit time-tag. On the other hand, if we allow for a more general notion of a time-tag, which may include the association of contextual information with events when they occur, then this model becomes hard to distinguish from the other location-based models. So it will be more fruitful to consider these other, more well-defined models, as we shall do next.

6 The Perturbation Model

The perturbation model has been one of the most influential models of memory for time. It explains the

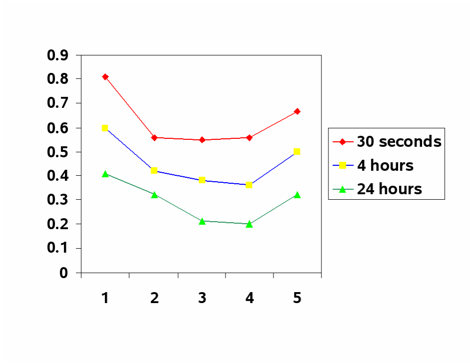

Figure 2: The proportion of correct responses as a function of input serial position when the reconstruction of order task was given after 30 seconds, 4 hours and 24 hours respectively. Adapted from [13]

data obtained for short-term memory recall of serial order to a remarkably accurate extent. The perturbation model was first proposed by Estes in 1972, later it was extended for multilevel perturbation processes by Lee and Estes [2], [8]. Nairne [12] further used this model to account for the observed properties of long term memory for time as well.

6.1 The Basic Model

The model was proposed to account for the positional uncertainty of recall of sequentially presented items. If subjects are presented with a list of words, and then later asked to recall the words in the correct sequential order, it is observed that they mostly tend to recall a particular word at its originally correct position, and the chance of recalling the word at a different position decreases with increasing distance from the original position. The plot of the proportion of responses versus the serial position, called the *positional uncertainty gradient*, is shown in Figure 2. Also, the recall of the words shows a distinct primacy and recency effect, as shown in the figures.

Estes accounted for the above data by assuming that the noise in the memory system causes random perturbations of the traversal times in delay loops [2]. Therefore the order information of a particular word can be lost if it is perturbed out of its original position. The issue of order versus item information is discussed later in this paper.

Mathematically speaking, the model is formulated as follows : Suppose that we are dealing with

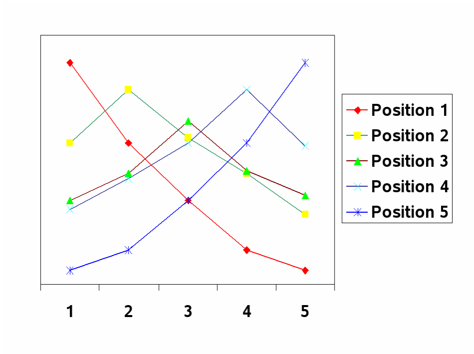

Figure 3: The positional uncertainty gradient curve. Adapted from [13]

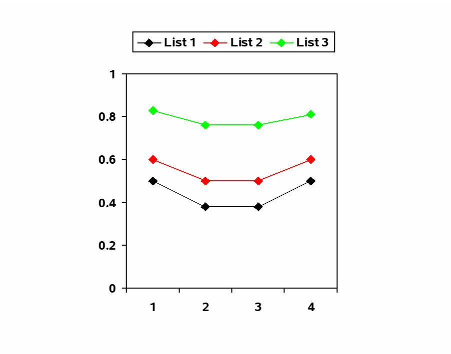

Figure 4: Outcome of Lee and Estes experiment, 1981. Adapted from [8]

perturbations along one dimension only. Suppose that the probability that an item will undergo perturbation from its original position is θ. Perturbations are assumed to occur at discrete time intervals. The probability that an item at position n and time t is given by $x_{n,t}$. Then the probability that the item is at the same position at time $t+1$ is given by the equation

$$x_{n,t+1} = (1-\theta)x_{n,t+1} + \left(\frac{\theta}{2}\right)x_{n-1,t} + \left(\frac{\theta}{2}\right)x_{n+1,t} \quad (1)$$

In the equation, we assume that the movement in either direction is equally likely. Therefore, for the endpoints, the equation takes a slightly different form, given by

$$x_{1,t+1} = \left(1 - \left(\frac{\theta}{2}\right)\right)x_{1,t} + \left(\frac{\theta}{2}\right)x_{2,t} \quad (2)$$

and similarly for the other end point too. Further, Estes assumed that the perturbation occur *after* the sequence is presented, and *not* during the time the sequence is presented. This was done to account for the symmetry of the positional uncertainty gradient curve.

Using the above recurrence relation, the probability that the item will be at a given position after a certain time interval can be calculated. Using a value of $\theta = 0.15$, the positional uncertainty gradient so obtained matched excellently with the experimentally obtained curve [12]. The Perturbation Theory is able to account for many other observed properties of memory for time as well [13]. The primacy and the recency effect can be easily explained, because the end items are less likely to perturb than the middle items, since at the ends the perturbation can take place in only one direction. The fact the better accuracy with longer intervals is observed, is readily understood because the longer the interval, lesser is the perturbation probability θ and hence better the accuracy. Similarly other observed properties can also be explained using the perturbation theory.

6.2 Multilevel perturbation process

Lee and Estes carried out a series of experiments in 1981 to test if the perturbation theory can be extended to observed behavioural data for multi-dimensional storage of data for time [8]. In their experiment, they presented to the subjects a list of 4 letters, and 3 such lists were presented, each separated by a distractor item. Then they asked the subjects to recall each of the item, and write the order in which the lists were presented, as well as the correct order of the letter within the sequence. For example, in one experiment, the lists presented to the subject were (B,F,J,K), (1,4,7,9) and (L,N,Q,R), and each list was separated by an exclamation mark (!).

The outcome of the experiment is shown in figure 3. Lee and Estes plotted the probability of recall of an item at its correct position (irrespective of the particular list in which it was recalled). The curves obtained are shown in figure 3. It is quite clear from the plots that for each of the lists, the probability of recall of an item at its correct position is quite similar to that in a single dimensional perturbation process.

Lee and Estes then proposed a more complex math-

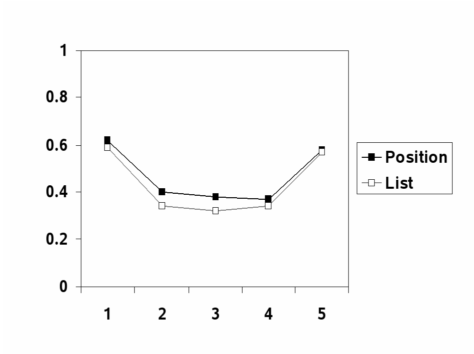

Figure 5: Experimental results of Nairne's experiment, 1991. taken from [12]

ematical model for explaining the above observed data [8]. They argued that apart from the perturbation that takes place within a list, an item can also get perturbed from one list to another. They termed such a perturbation process as the 'z' process. Mathematically, if $z_{t,n}$ is the probability that the item is in the *nthlist* after a time interval t, then the probability that the item is at the same position in the next time interval is given by

$$z_{t,n+1} = (1-\theta)z_{t,n} + \left(\frac{\theta}{2}\right)z_{t,n+1} + \left(\frac{\theta}{2}\right)z_{t-1,n} \quad (3)$$

Based on the above equation, they proposed a complex mathematical model for multidimensional perturbation processes that successfully accounted for the behavioural to a remarkably accurate extent. More details of this model can be found in [8]

Nairne performed a similar kind of experiment in 1991 [12]. He presented to subjects a 5 lists of words, each of which had 5 words. The subjects were then engaged in a distractor task. After this, the subjects were presented with the 25 words earlier shown to them, and then asked to place the words in the correct list, as well as at the correct position within the list. Nairne tabulated two sets of data : One was the proportion of successfully placing a word in the correct list (irrespective of the portion within list at which it was placed), and second was the proportion of successfully placing a word at the correct position (irrespective of the list in which it was placed). In both the cases, the bow shaped recall showed the same primacy and recency effect as shown in the figure. This again confirms the hypothesis that perturbations can occur along multiple dimensions too.

6.3 Item versus order information

One long standing debate on memory for time has been regarding the item versus order information in memory [13]. When a subjects fails to recall an item, is it because he is lost the information about the item, or is it just that the item is still there but its precise temporal occurrence has been forgotten?

Lee and Estes, using their multidimensional perturbation model, argued that the item information is not forgotten [8]. What happens is that, the item is merely perturbed from one dimension to another dimension in the perturbation process. Thus, if the item gets perturbed to another dimension, then he will not be able to recall the item properly.

Another issue in this regard has been the effect of acoustic similarity on the correct order of recall. For example, if in the original experiment of Estes, if the letters presented are acoustically similar (e.g. B,P,C,V), then does this affect the recall order in any way ? Many series of experiments have been conducted, however the results obtained by different researchers have not been very consistent [2]. Some report that acoustic similarity aids in serial recall, while others report that there is actually degradation in performance. Lee and Estes argued that the effects of acoustic similarity on item recall depend strongly on other factors. For example, difference in observations will be obtained if the subjects are made to recall the items than to recognize the items, since these two processes give different results under incidental and intentional memorizing conditions.

6.4 Perturbation Theory and Long Term Memory

Nairne has presented various experimental results to show that perturbation theory can also account for positional uncertainty in long term memory as well [12]. According to Nairne, performance in the long term case clearly mimics, in many respects, performance in immediate memory. In both the short term case as well as the long term case, the retention of temporal order produces bow-shaped serial position curves and error gradients that are approximately symmetrical about the true position. Nairne said that it is simply a matter of specifying the perturbation rates, and dealing with the question of whether the perturbation process operates in relative or absolute time.

7 The Inferential Model of Memory for Time

The third location-based model of memory for time is the inferential, or reconstructive model. Unlike the perturbation model, which provides a detailed, quantitative account of memory and makes concrete predictions, this model takes a much more general approach. The model fits in well with our intuition about how human memory functions, and it does a good job of explaining all the observed properties of temporal memory. However, it is largely qualitative, and is unable to make specific, experimentally verifiable statements.

7.1 The Basic Postulates

According to Friedman [6], people use "general time knowledge and inferential processes at the time of recall" to infer or construct temporal sequences. Information about the environment, as well as one's own internal state, is said to be encoded along with particular events. When one is asked to give the time of an event, this information is retrieved and used to get a time judgment. The way this is done is that the information is interpreted in the context of one's knowledge of natural temporal patterns. For example, if I remember an event as having occurred at or near lunchtime, it tells me the time of day when it happened. If I remember that it was raining very heavily at the time, it gives me an idea of the season. I might recall having been in a very relaxed mood at the time, indicating a holiday or vacation period.

The application of reconstructive processes for dating memories of public or private events is assumed to draw on a rich knowledge bank of social, natural and personal time patterns. Examples include facts such as the length of an undergraduate college degree program being 3 or 4 years, my usual dinner time being around 7:30 PM, or there being dense fog on winter mornings. Such knowledge can be correlated with the exact dates which have been memorized for a few seminal events, to arrive at accurate time judgments for our memories. To give another example, I may remember that a particular incident occurred during my college's annual cultural festival, while I was coordinating one of the events. Knowing that the festival is held during the autumn, and that I had been part of the organizational team in my junior year, allows me to place this event quite accurately in time.

As opposed to the notion of a time stamp, in the inference model there is no assumption that specific temporal information is assigned at the time of encoding; general contextual information is sufficient. There is also no notion here of the perturbation of the location of an event, either backward or forward in time. As we shall see next, this model, despite its apparent simplicity, is able to account quite well for experimental data.

7.2 Explanation of Observed Properties

All of the properties mentioned in section 2 can be explained within the framework of the reconstructive theory. The recency effect follows from the fact that more contextual information is available for recent events, so better time judgments can be made for them. Primacy is explained by the fact that more information will be available for landmark events, such as the first day at college, so they can be dated more accurately. Telescoping effects can also be explained in a similar manner, since older events will have less associated information available, so there will be a tendency to misjudge their time. This effect will be more pronounced in the forward direction, as the recent events will be accurately placed, and additionally, some of the older events will also be construed as recent.

The fact that it is easier to relatively date events with longer intervals between them can be seen as an instance of a general principle of cognition: the more the distance (along whatever scale/dimension) between two things, the easier it is to distinguish between them. When two events are separated by a large temporal interval, there will generally be a significant difference in the amount and nature of contextual information available for them, making it easy to decide which one occurred earlier. On the other hand, making the same kind of distinction for two events which took place close together will be harder, and more prone to error.

The independence of time scales is easily and naturally explained by this model, since different kinds of information are helpful in estimating times on different scales. Something (such as it having been lunchtime) may help to place an event accurately on a fine time scale like hour of day, while providing no clue about position on a coarser scale like time of year. Boundary effects can be accounted for in two ways: rounding and landmark events. Rounding refers to the fact that when people are unsure of the time of occurrence of an event, they tend to round it to some meaningful time, such as 14, 21, 30 (on the days scale) or 6, 12, 24 (on the hours scale). These meaningful times can be expected to serve as boundaries. The other process leading to boundary effects is the availability of more contextual information for landmark events. So the boundaries on any scale are landmarks, in some sense, to which more importance is attached than usual.

The concept of boundaries is also a fundamental feature of perturbation theory. Perhaps, this is a pointer to a way of combining the two theories. One possibility might be to incorporate the kind of meaningful times seen above, as boundaries within the perturbation model. This looks to be a promising direction for future research.

8 Relative Time Theories

The third class of theories are based on the concept of relative time. Here, temporal information is stored in memory in the form of connections between events. No appeal is made to information derived from 'distance' or 'location'. There are two theories within this class: associative chaining and order codes.

8.1 Associative Chaining Theory

According to this, events are simply linked with their immediate successors in time. These links are used to figure out the temporal separation between events. For example, in one of the versions of this theory, TODAM, proposed by Lewandowsky and Murdock [10], the order of items is coded by pairwise associations between successive items. During an experiment, these associations would be formed between successive words on a list. In real life, such links may be created between, say, adjacent semesters during one's college years. One of the problems with a chaining theory is, what happens if one link is lost? Does the entire chain after that become inaccessible? TODAM offers a solution to this, essentially by using the item that is (incorrectly) recalled in place of the lost link, to try and get to the next item. This approach seems to work most of the time.

One significant problem with this theory is that it doesn't specify on what scale succession is coded. It could be minutes, hours, days, or even some longer scale. If the coding is on some short scale, it would seem to imply having to run through long chains of links when ordering events on large scales. It also does not explain why events separated by longer intervals should be easier to order, since seemingly ordering information for adjacent events should be more readily available due to the associations between them. Another issue is that this model can account only for relative time judgments. It gives no indication as to how the absolute time of any event can be known.

8.2 Order Codes

In this model, temporal information is added to stored items even after their occurrence. Categorical links get formed between items. Whenever a new incoming item causes the recall of an older one, a link gets formed between them, and their order is automatically stored. So, chains of semantically related events can be formed in the memory. For example, at the time of terrorist attack on the Indian Parliament in December 2001, the WTC attacks of 3 months earlier would have been recalled, and a strong link formed between the two. In this model, there is no requirement that linked events be contiguous in time. So the scale problems of associative chaining are avoided.

According to the order code model, you would expect related events to be ordered more accurately than unrelated ones. To test this, Tzeng and Cotton [16] conducted an experiment where they presented subjects with a list of 50 words, taken from 10 different categories. Some of the categories were flowers, animals, farm tools and so on. At test, the subjects were given pairs of words and asked which one had been presented earlier in the list. Some of the pairs were same-category (like *rose* and *dahlia*), while others were unrelated (like *horse* and *rake*). It was found that accuracy for same-category pairs was significantly greater, 80% as opposed to 66% for unrelated pairs. This clearly supported the order code model. However, the model does have some problems. Like associative chaining, it offers no way of knowing the absolute time of an event. Also, it cannot explain how two completely unrelated events are ordered.

9 Summarizing the Models

As we have seen, a large number of models exist which attempt to account for memory for time. Most of them are unsatisfactory, being unable to account for all the observed behavioural characteristics. Only two models, the perturbation model and the inferential model, seem to be able to provide a coherent account of temporal memory. We have also seen a possible direction for bringing these two models together. However, it is hard to say whether all the properties exhibited by human memory can really be incorporated within a single theoretical framework. Multiple processes seem to be at work, and each of the models discussed can account for at least some of the data quite well. We may well ask, what does memory consist of? Is it merely a patchwork of several independent, unrelated systems working in unison, or is it a single, all-encompassing entity? Hopefully, time will provide the answer.

10 Autobiographic Memory and Self Memory

10.1 Properties of Autobiographic Memory

Autobiographical memory is the memory for events that happens during one's own lifetime [13]. Autobiographical memories present some interesting properties. It is highly dynamic, constructive, transitory and are generate from an underlying knowledge base.

A significant amount of work in this area has been done by Conway and Pleydell-Pearce [1]. According to them, there are three main types of knowledge that are stored in the Autobiographical Memory. They are:

1. *Lifetime periods*: Lifetime periods represent distinct periods of time during one's life. For example, when I was in school, when I was in college, when I was working in this particular company and so on. The start and end points of these periods may not be quite distinct, or may be overlapping, but nevertheless, it does represent major phases in one's self life.

2. *General events*: These are more specific than the Lifetime periods. It can include both unique and repeated sequence of events during one's lifetimes. For example, when I was in school, I used to go by bus, when I was in college, I was an active football player and so on. These are often clustered, and the organization for such events may not be necessarily chronological.

3. *Event-specific events*: This part of Autobiographical Memory stores the particular events that take place during one's lifetime. Like a person may remember about a particular drama he enacted in school and which was a great success for that person. Usually, these events are linked in memory with the general events. If these links are not rehearsed, then memory for these events can be quickly forgotten.

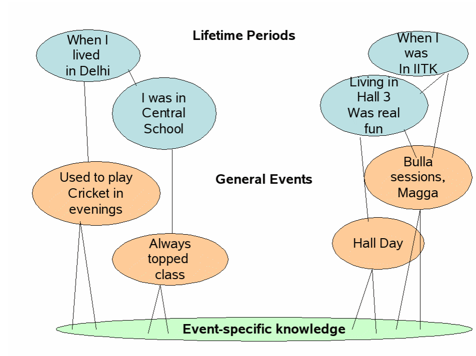

Figure 6: The three components of the autobiographical memory knowledge base. Adapted from Conway and Pleydell-Pearce [1]

10.2 Self Memory System

This term was coined by Conway and Pleydell-Pearce[1]. Self Memory system is the Autobiographical Memory in conjunction with the working self. The term *working self* is used to describe the self in the same way that the term *working memory* is used to describe memory. The working memory is like a set of control processes that coordinate and modulate other computationally separate systems, and working self is a subset of working memory control processes organized into interconnected goal hierarchies that function to constraint cognition and behaviour. In self memory system, therefore, goal and motivation are significantly important since they dictate both the encoding and retrieval of autobiographical knowledge.

10.3 Retrieval from autobiographical memory

Clearly autobiographical memories are transitory and shaped by interaction of the working self and the knowledge database. The retrieval of information from autobiographical memory depends mainly on the retrieval conditions and cues. Many times, recall of one event acts as a cue for the next event, then this event triggers the recall of a third event, and so on. The principal of encoding specificity is also quite valid for recall in such a situation. For example, a grown up person may not recall his school day memories as such. However, if he happens to visit his school, then he will be able to recall more things about his school days, since now the context of the school provides an important clue for retrieval from the long term memory.

When people are asked to recall events from their life, the result observed shows a trend quite similar to shown in the figure [1]. Generally adults have very few memories of early childhood - from age of 0 to 5 years. This is called *infantile amnesia*. Then there is an increase, known as *reminiscence bump*, for events that occurred between the ages of about 10 and 30. Fewer events are recalled from middle age, then there is an increase for events from later in life.

The infantile amnesia is accounted by the fact that the human cognitive system is very less developed in the initial stages of life. Also, there is no motivation as such for infants to remember the events that occur at that period. More intriguing, however, is the reminiscence bump and then the fall in the relative number of recalled memories.

The main reason for reminiscence bump is that, most of the first-time experiences occur between the ages of 10 and 30, and therefore these are more distinctly remembered. After this , the life of a typical adult is relatively stable, and there are fewer

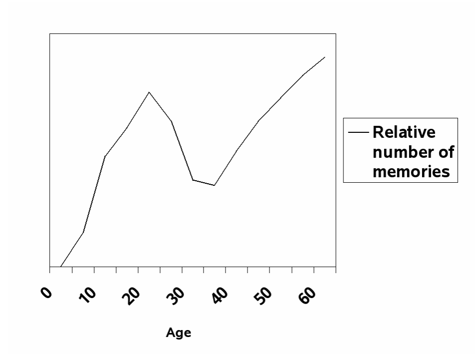

Figure 7: Graph showing the relative number of memories produced as a function of the age at which the event occurred. Adapted from Conway and Pleydell-Pearce [1]

distinctive events, and hence the lesser number of recalled memories from this period. After this, the rise in the curve is mainly attributed to the recency effect, that is, a person remembers an event which happened closer in time more clearly than those which took place quite some time back.

11 Current State of Research in Memory For Time

The properties of memory for time have been quite extensively studied and recorded in the literature. Also, there are a number of models that have been proposed for explaining the observed behavioural data, the prominent ones being the perturbation theory and the reconstruction theory. At present, significant work is being carried out on studying the propertied of autobiographical memory and self memory systems. However, very little work has been done on the neural basis of memory for time. Given the current state of research in the field of neural memory systems, the time is not far when memory for time at the neural level will also become a prominent area of study.

12 Conclusion

In this paper, we have briefly listed the observed properties of memory for time, looked at the behavioural data, described a few of the prominent memory models, and also discussed self memory systems and autobiographical memory systems. Even though a significant amount of research work has been done in this field, there is still a lot of scope for experimental studies, especially in the area of neural basis of memory for time. Memory for time is indeed a fascinating area in Cognitive Psychology and many more mysteries still remain to be answered.

References

[1] Conway and Pleydell-Pearce (2000). The construction of autobiographical memories in the self memory system. *Psychological Review.* system. *Psychological Review*, 107, 261-288.

[2] Estes, W.K. (1972). An associative basis of memory for coding and organization in memory. In A.W Melton and E. Martin (Eds.), *Coding processes in human memory* (pp. 161 - 190). Washington, DC: Winston.

[3] Friedman, W.J. and Wilkins, A.J. (1985). Scale effects in memory for the time of events. *Memory and Cognition*, 13, 168-175.

[4] Friedman, W.J. (1987). A follow-up to "Scale effects in memory for the time of events": the earthquake study. *Memory and Cognition*, 15, 518-520.

[5] Friedman, W.J. (1990). *About Time.* Cambridge, MA: The MIT Press.

[6] Friedman, W.J. (1993). Memory for the time of past events. *Psychological Bulletin*, 113, 44-66.

[7] Hintzman, D.L., Block, R.A. and Summers, J.J. (1973). Contextual associations and memory for serial position. *Journal of Experimental Psychology*, 97, 220-229.

[8] Lee, C.L. and Estes, W.K. (1977). Order and position in memory for letter strings. *Journal of Verbal Learning and Verbal Behaviour*, 16, 395-418.

[9] Lee, C.L. and Estes, W.K. (1981). Item and information in short-term memory: Evidence for multilevel perturbation processes. *Journal of Experimental Psychology: Human Learning and Memory*, 7, 149-169.

[10] Lewandowsky, S., and Murdock, B.B., Jr. (1989). Memory for serial order. *Psychological Review*, 96, 25-57.

[11] Murdock, B.B., Jr. (1974). *Human memory: Theory and data.* Potomac, MD:Erlbaum.

[12] Nairne, J.S. (1991). Positional uncertainty in long-term memory. *Memory and Cognition*, 19 (4), 332-340.

[13] Neath, I. and Surprenant, A.M. (2003). *Human Memory: An Introduction to Research, Data and Theory, second edition.* Belmont, CA: Wadsworth, 291-314.

[14] Shannon, B. (1979). Yesterday, today and tomorrow. *Acta Psychologica*, 43, 469-476.

[15] Thompson, C.P., Skowronski, J.J., and Lee, D.J. (1988). Telescoping in dating naturally occurring events. *Memory and Cognition*, 16, 461-468.

[16] Tzeng, O.J.L. and Cotton, B. (1980). A study-phase retrieval model of temporal coding. *Journal of Experimental Psychology: Human Learning and Memory*, 6, 705-716.

[17] Wagenaar, W.A. (1986). My memory: A study of autobiographical memory over six years. *Cognitive Psychology*, 18, 225-252.