Placing Information on Pegs of Time: How to Use What we Know About Serial Order Memory for Better Representation and Retrieval of Knowledge

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In this paper, I explain how memory underlies knowledge and go on to review research on serial position effects in short term and long term memory. Serial position effect is the change in memory performance of items over positions in a list. This effect is crucial for learning and remembering sequences of information, such as phone numbers, chronological order of events, and so on. Eventually, I integrate the findings from cognitive psychology to provide solutions for better teaching and learning.

Keywords: Knowledge, Memory, Serial position effects

Introduction

What is the relationship between knowledge and memory?

The human mind is endowed with the ability to learn and remember information. Organized information consolidates to form knowledge. Well –represented knowledge reflects veridical encoding, maintenance and useful retrieval of information, such that new units of learnt information may be updated and integrated with existing ones in the absence of the original sources of information. Knowledge, thus defined, is identical to memory: It is made up of long -term memory that can last anywhere between minutes and a lifetime, as well as short-term memory that holds information for up to a few seconds acts as a buffer (Atkinson & Shiffrin, 1968) to store information temporarily before it is integrated with pre-existing knowledge in long term memory format.

Temporal dimension of knowledge/memory in an educational setting

Knowledge may be structured on various dimensions, such as, 'when or following what did a given event occur', 'what happened following a given event' and 'where did the given event occur'. Effective access of knowledge along one or more of these dimensions is crucial in a classroom situation. For instance, it is important to remember when the Roman Empire collapsed if one is in a history lesson (temporal dimension) whereas a geography lesson may call for retrieval of the location of a city named Kolkata (spatial dimension). The temporal dimension in knowledge is tapped when information regarding when or in what order a set of information units/events occurred is required. It may involve short-term memory (say, a set of numbers that can be used in a math problem), long term memory (say, a dynasty of kings in chronological order) and/or a combination of both. Thus, the temporal dimension addresses a single or a series of representations of items or events arranged on a time-scale in a given order.

Scope of the present paper

Researchers have studied the temporal dimension in both short term and long term memory from serial position effects. The serial position effect is a robust phenomenon in which items presented in the beginning and the end of a study list show a definite retrieval advantage over those in the middle of the list. This phenomenon renders the function of accuracy plotted against serial position in a memory list a distinct bow-shape. The advantage of items in the beginning of the list is described as the primacy effect, and the advantage of the items in the end of the list is described as the recency effect.

However, there is a lack of scientific work that bridges the application of research findings in serial order memory to an educational setting. Such applications are necessary as present day educators strive to endow learners with techniques to grapple with temporal organization of information in an independent manner. Moreover, as we sail towards a future of e-learning, the temporal dimension of information, along with other dimensions, requires to be presented effectively. In the rest of my paper, I review the findings in the memory literature and identify possibilities to apply them to encoding, representation and successful retrieval of knowledge organized along the temporal dimension.

Review and Application of Research on Serial Order Information in Memory

Serial order information in short term memory

The investigation of the processes which underlie the generation of serial position curves led researchers to come up with models on how items are represented over a time scale in short-term memory. Presently, two families of models describe how order information is maintained in short-term memory (Farrell & McLaughlin, 2007). One family supposes that order information is remembered in terms of the relationship between items present in a given memory set. Examples of such models are chaining models (Lewandowsky & Murdock, 1989; Murdock, 1995) and ordinal models (Farrell & Lewandowsky, 2002; Page & Norris, 1998). According to the chaining models, memory of one item in a list acts as a cue to remember the next item in the list and so on. These associated pairs between successive items are the chains. Items are represented as vectors, and individual items form pairs by the process of convolution. During retrieval, the encoded items are operated on by the process of correlation, and their separate identity can be retrieved from the chain. According to the ordinal models, an item is first associated with itself to a vector, which in turn is embedded in the vector matrix of all encoded items. Successively studied items are encoded with gradually decreasing strength. During retrieval, items are selected from the vector matrix until the one closest to the memory demand is obtained.

The other group of models describes order information to be remembered as being placed on an external representation, such as a time-scale. The temporal context models (e.g. Brown, Preece & Hulme, 2000; Howard & Kahana, 2002) and the temporal distinctiveness models (e.g. Brown, Neath & Chater, 2007; Glenberg & Swanson, 1986; Neath, 1993) belong to this group. According to the temporal context model, an item is encoded with a time-stamp or a vector for the specific point on the time-scale. During retrieval, the present temporal context provides the cue which is matched with the temporal context during encoding to retrieve the correct item. The temporal context for the correctly retrieved item then generates the context for the next item on the list, and so on. As per the temporal distinctiveness models, items are remembered based on the length of the time gap between their presentations in a list. In other words, items that are isolated temporally from their neighbours in a list show a benefit at retrieval. The temporal distinctiveness model is an adaptation from the perturbation model (Estes, 1972; Lee & Estes, 1977, 1981). According to the perturbation model, items in a list have more propensity to be confused with their immediate neighbours on the list. Wicklegren (1967) further pointed out that forgetting of items within a list is independent of forgetting which list the item is from.

All these models are based on empirical findings from experiments in the laboratory and computer simulations. They are able to account for serial position effects in the data on which they were based. However, other findings from experiments (e.g., Farrell & McLaughlin, 2007; Nimmo & Lewandosky, 2006; Saito, 2001) that have attempted to understand how order information is maintained in memory do not unanimously support any one of these two groups of models. Nevertheless, there are findings which have demonstrated application of a combination of these models. Some of these results, as under, are very useful in understanding how learning techniques may be used to enhance encoding and retrieval of knowledge along the temporal dimension.

Welte and Laughery (1971) examined the effect of decreasing and increasing presentation times of a set of 9 digits starting at 500 milliseconds with an increment of 200 milliseconds. They observed that items that were differentially spaced in time were remembered better than items equally spaced in time during both free recall and serial recall. Neath and Crowder (1996) carried out an experiment in which they varied interval between two consecutive items in lists made up of 5 items. They observed that primacy effects were greater when the interval between items decreased over serial positions than when the time interval increased over serial positions. Recency effects were greater when the time interval increased over the list. However, Lewandosky and Brown (2005) did not find such systematic effects when they randomly changed the time interval after study items within a list: The beneficial effects of temporal isolation were dependent on the differential time intervals following presentation of an item in a study list.

Furthermore, Farrell (2008) carried out a set of experiments where participants were either instructed to group study items (digits) or these study items were grouped by temporal spacing. Furthermore, the participants were cued beforehand that they would have to report the order or timing of the items or given the same cue following the item presentation. Time gap between units of information during retrieval of item positions and identity was same as that during encoding, and this independent of whether items were grouped temporally or by participants. Moreover, when participants knew that they had to recall timing and order information of the items, they did better when items were temporally isolated from that one another than when they were grouped. Baddeley (1966) carried out an experiment where participants had to recall a list of eight words similar in the way they sounded (phonology) or similar in meaning (semantics) in serial order from short term memory. Similarity on both the dimensions of semantics and phonology helped memory of the items. More recent studies (Poirer & Saint-Aubin, 1995; Saint-Aubin, Ouellette, & Poirier, 2005) have manipulated the degree of semantic similarity in words in serial recall experiments by using words from different categories or same categories, such as animals. Results showed that participants remembered similar words better.

Guay (1986) studied whether using a cognitive strategy of time estimation would cause proactive interference in remembering visual durations in the order of 1, 4, or 8 seconds following no rest, 15 seconds and 30 seconds of rest. The results showed that active estimation of time did not harm performance, but time-based forgetting caused errors in reproducing the longer durations of 4 and 8 seconds. The results from these studies can be applied in the classroom to promote better learning experience and veridical acquisition, representation and retrieval of knowledge. I summarize the possible applications below.

— Similar retrieval contexts during encoding and retrieval benefit serial recall from short term memory. In this case, the context could be the temporal context, the serial order of information, or relative position of items. For example, if encoding and recall of a list of words is always in the same order, the temporal context in which each item is retrieved (before and after other items) remains the same during encoding and retrieval.

— Positions of items, when relevant to knowledge acquisition should be distinctive. This may be achieved by instructing learners to pay attention to the temporal sequence in which they are presented, numbering them and so on.

— Items in a study list should have different time gaps following it for them to be remembered better. For example, if a list of names is to be learnt, the time gap between presentation of the first and second names on the list should be different from the time gap between the second and the third name, and so on.

— Words that are similar in meaning have a greater benefit than those that belong to different semantic categories when they have to be recalled in order. Phonological similarity is likely to benefit short term memory as well. For example, new words that are names of animals and food items should be presented in two different lists.

— Retrieval of items could be affected due to time-based decay of learnt items if the presentation times of study items are too long. For example, if one item on a list stays on for between 4 seconds and 8 seconds, items that were learnt before are forgotten.

Serial order information in long term memory

Resilient representation of information in short-term memory results in its transfer into the long term memory. Different mechanisms have been put forward to describe how this transfer takes place. Atkinson and Shiffrin (1968) has identified that an elaborative rehearsal process links short term memory with long term memory, whereas according to more recent models (e.g. Burgess & Hitch, 2005), a Hebbian connectivity between memory traces, strengthened by repetition, has been proposed. According to Burgess & Hitch (2005), repetition of similar sequences in a study list generate a cumulative matching process via which a similar temporal context signal is generated for those sequences. These sequences are then grouped together as a family in long term memory or the knowledge base. During retrieval, a 'competitive queuing' (Grossberg, 1978; Houghton, 1990) process occurs, where the item with the highest strength during encoding is recalled first, and then inhibited for the next item to surface.

Once items from short term memory have been transferred to long term memory, retrieval from the knowledge base shows serial position effects as seen in short term memory in some studies (Nairne, 1990, 1991) and not others (Glenber, et al., 1980). Nairne conducted experiments where participants were given a surprise recall test ten minutes after they had rated words on a pleasantness-unpleasantness dimension. The ten minute interval was filled with a distracting math problem task. During recall, the participants showed similar serial position effects as in short term memory. Furthermore, the erroneous responses appeared to drift to the immediate neighbourhood of the correct positions, as expected by the perturbation model for short term memory (Estes, 1972; Lee & Estes, 1977, 1981).

On the contrary, Glenberg et al. (1980) could experimentally dampen the primacy effect in long term memory, by blocking rehearsal of the first few pairs of items in the study list and inducing incidental learning of all word pairs. Further, they confirmed that list length had an effect on recency effects, unlike in short term memory (Murdock, 1962; Postman & Philips, 1965). From these results, Glenberg et al. (1980) concluded that retrieval of items in long term memory is dependent on temporal cues from the retrieval context. Further, Whitten (1978) showed that varying the position in the lists from which items had to be recalled from long term memory did not affect the probability of recall. Their finding suggested that limits on retrieval were put not by serial positions, but a deficit in the system which generated retrieval.

At the face of these mixed findings, there is still no model that can unanimously describe serial position effects during retrieval from long term memory. One of the most influential models in this area is Anderson's Adaptive Character of Thought-Rational (ACT-R) model (Anderson & Matessa, 1997). According to this model, declarative knowledge units contain information about positions of items in lists and groups containing the lists. A set of production rules operate on declarative memory during retrieval to access positions within list/groups of items. Knowledge units matching a given position are retrieved according to the production rule. Serial position effects occur when there is a partial matching between the position recalled and the actual position to-be-recalled within a list.

Besides modeling efforts to describe serial position effects in long term memory, studies have also been carried out to explore how information is organized along the temporal dimension of long term memory when research participants are engaged in tasks outside the laboratory. In one study, Baddeley, Lewis and Nimmo-Smith (1978) asked participants when they had last participated in laboratory research. The error in the dates they reported was proportional to the time that elapsed between the actual day they participated in research and the day when they were asked to report when they had done so. Also, dates confused with the actual dates were close on the time scale to the actual dates. These results verify a perturbation effect in long term memory, as shown by Nairne's (1990, 1991) laboratory research.

Huttenlocher, Hedges, and Bradburn (1990) carried out an experiment in which they asked participants when they had last taken part in some activity, for example eating fish. Their findings were similar to those of Baddeley et al. (1978) in that errors in reporting increased with increasing time lapse between date of activity and date of reporting. Furthermore, Huttenlocher et al. (1990) pointed out that reporting time of events in a naturalistic setting involved retrieval of temporal dimensions organized at multiple levels, such as days, months and years. This could potentially cause recall errors if participants focused attention in the wrong dimension. For instance, focusing on retrieving 'which year' information could cause inaccuracy in the 'what date' dimension and so on.

Healy, Shea, Kole, and Cunningham (2008) carried out a series of three experiments to understand how order information is reconstructed in long term memory. They used presentations of lists with 20 names, and the research participants had to report the order of 12 members of each list. The order of the items in the study lists were varied spatially or temporally. In all cases, the participants had to work on a letter detection task after the stimuli were presented, in order to wipe out effects of short term memory on their performance. Participants were more likely to use absolute positions of the items in the list to reconstruct the study items during test. Moreover, greater frequency of presentation of items that were rated as familiar by the participants as well as reinstatement of positions had a beneficial effect on memory of those items and positions.

Even though the discussion whether serial order effects are similar in origin for short term and long term memory is unresolved, veridical short term memory has the potential to increase the probability of accurate encoding of information in long term memory. Therefore, it is likely that long term memory could partially benefit from the techniques that benefit short term memory. In addition, the present findings in long term memory research outlined above can be extended in the following ways for better learning in the classroom.

1. Positions of items in a list should be made distinct in long term memory to prevent perturbations using exercises such as asking learners to classify items based on position. For example, a list of names of Emperors in a dynasty can be rehearsed according to the dates they ruled as well.
2. Learners should engage in more frequent rehearsal of items that are in the middle of study lists to balance out primacy and recency effects.
3. Learners should focus on the relevant level of temporal organization for specific information. Strategies for temporal organization may be retrieved from long term memory. For instance, when the Independence Day of the United States is to be remembered, the focus of attention during encoding (and retrieval) should be on the date, and not the year.
4. Learners should encode items closely spaced on the temporal dimension with greater strength, as they are more likely to be confused.
5. Learners should reinstate encoded information in long term memory continuously by rehearsal to keep the encoded items active between study time and retrieval time of learnt information.
6. Learners should be made familiar with novel objects/symbols/events before they are made to learn their sequences.

Future Direction of Research

This paper highlights the relationship between the temporal organization of knowledge and serial position effects and goes on to propose unexplored ways to apply laboratory findings in memory research to improve learning and teaching performance. Even though the proposed techniques are based on existing body of basic laboratory research, they need to be applied in a field-setting to verify their effectiveness. Future studies focused on examining the outcomes of these techniques should be in order to help educators as well as learners to represent and access knowledge effectively along the temporal dimension. Such studies should aim to explore how each of the proposed techniques deals with serial position effects in both short-term and long-term memory of study material. Thus, the findings from the future studies will have the potential to identify useful methods for good temporal organization of knowledge as well as validate existing theoretical models that are based solely on laboratory research.

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