Investigations of short-term and long-term memory using the serial position curve

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ABSTRACT

We studied the predictive power of the Atkinson and Shiffrin model of a multicomponent structure for human memory (containing both short-term and long-term subsystems) by administering five verbal free recall tests with varying conditions to a group of 10 M.I.T. students. The conditions included a practice and a baseline condition, a long retention condition, a mental arithmetic condition (brief distractor task following presentation phase), and a controlled rehearsal condition. We observed the effects of these experimental manipulations on the serial position curve, and found that, as expected, long retention abolished the recency effect, mental arithmetic abolished the recency effect, and controlled rehearsal abolished the primacy effect. Although our standard serial position curve was not identical to canonically-shaped serial position curves, and although there were some deviations in our data from what would be predicted by multicomponent theory, these differences may all be explained by a variety of confounding factors, the most important of which was our small sample size and the absence of any statistical analysis. In general, then, our findings support Atkinson's and Shiffrin's model for memory as a multicomponent system.

INTRODUCTION

Since the 1960's, it has been thought that human memory is not a single homogenous storage unit, but rather consists of several different components, each with its own unique properties (Capitani et al., 1992; Miller et al., 1997). Two major components that have been suggested by the proponents of such a multicomponent (multiprocess) theory are those of short-term memory (STM) and long-term memory (LTM). It is thought that all information must first pass through STM when entering the human memory system, and that STM has a limited capacity of 7-9 "chunks" of unrelated information, which are easily retrieved. When this memory subsystem is filled to capacity (for example, by the presentation of more than 7-9 unrelated words in a verbal free recall experiment), an item may be displaced from it by a similar item (this is known as the "displacement principle"). Such a displaced item would be forgotten, unless it had already been transferred to LTM. Information enters LTM from STM when a control process (e.g., image-formation or rehearsal) is carried out; an item that remains in STM for a longer period of time has a greater likelihood of being operated upon by some control process, and thus more of a chance of entering LTM (Atkinson and Shiffrin, 1971; cited in Miller et al., 1997). For its part, LTM has a much larger capacity than STM; because of the large number of items stored here, retrieval of information from LTM is organization-dependent (unlike retrieval from STM) and is, on the whole, more difficult than retrieval of information from STM (Miller et al., 1997).

The operation of these two subcomponents of memory can be used to explain the serial position effect that is observed in tests of verbal free recall. This effect shows that subjects have a greater tendency to recall words that were presented earliest and latest in a list than to remember the middlemost items. Thus, the serial position curve displays a primacy effect (increased recall for earliest presented items) and a recency effect (increased recall for latest presented items) (See Figure 1 for an example of a classical U-shaped serial position curve, obtained by Capitani et al. (1992). The shape of the serial position curve may be explained in terms of Atkinson's and Shiffrin's multicomponent theory as follows: The first items presented in a list are able to remain in STM for a longer period of time before being displaced, and are thus more likely than later words to be rehearsed enough to enter LTM, from which they are retrieved at test. Thus, the primacy effect is thought to be subserved by the long-term component of memory. Those words that are presented at the end of a list have not yet been displaced from STM at test, and are thus more easily retrieved than the words in the middle of the list. The recency effect, then, seems to be subserved by the short-term component of memory. (Miller et al., 1997).

Aside from its importance in demonstrating the operation of two subcomponents of human memory, the serial position curve can also be utilized as a clinical tool for determining the type and extent of memory damage in patients with brain pathology or injury (Capitani et al., 1992). Thus, we decided that the multicomponent theory of Atkinson and Shiffrin warranted further investigation. We tested the predictive power of this theory by manipulating the conditions under which a verbal free recall task was performed. We explored the effects on the serial position curve of a 20-minute delay between presentation and test, a few minutes' delay with a distractor task to prevent rehearsal following the completion of the presentation phase, and controlled rehearsal of each item during presentation. Based on the work of other researchers, we expected that the long retention period would abolish the recency effect (since those items would not remain in STM over the delay), the distractor task after the presentation phase would abolish the recency effect (since those last few items could not be maintained in STM while the subject was engaged in the distractor task), and the controlled rehearsal would remove the primacy effect (since primacy seems to depend on rehearsal time, and here the earliest items and the middle items would be rehearsed the same amount) (Capitani et al., 1992).

METHOD

Subjects: Subjects were 10 M.I.T. neuroscience students, all between the ages of 19 and 21.

Procedure: Simultaneous group testing was conducted in an M.I.T. classroom. The five tests of verbal free recall were administered by three instructors, who operated all apparatus and recorded group data. For each test, the instructor first read the instructions to the subjects. Subjects were seated in front of a screen, on which words were presented with a slide projector. Each word was displayed for a constant period of time for each list; test periods were timed by the instructors. For each test, 15 words were presented; these words were common English nouns, verbs, and adjectives (e.g. "tree", "start", "gentle") which are frequently used in spoken or written communication. At test, students were asked to write on their data sheets as many words as they could remember, in any order. The instructors compiled the group results for each test condition and distributed this information to each student.

The five individual test conditions were as follows: practice, baseline, long retention, mental arithmetic, and controlled rehearsal. The practice condition was administered first; here, 15 words were presented for 2 seconds each (the delay between words was minimal), and test occurred immediately after the completion of the presentation phase. The baseline condition was exactly the same as the practice condition. The results of these initial two conditions were later averaged to obtain a standard serial position curve for this subject group (see Figure 2); it was necessary to include a practice condition to ensure that subjects understood the rules of the test, and the baseline condition had to be averaged with the practice condition to correct for any effects of familiarity with the test that may have occurred in the baseline condition. The long retention condition was administered next. Here, as before, 15 words were presented for 2 seconds each. However, students watched a 20-minute videotape between the presentation and test phases. Next, the mental arithmetic condition was administered. The presentation rate for the 15 words was maintained at 2 seconds; immediately following the presentation phase students were instructed to count backwards as quickly as possible from 201 by 3's (e.g., 201, 198, 195), and to write these numbers on their data sheets. After about 2 minutes, the distractor task was stopped and the test phase began. Finally, in the controlled rehearsal condition, 15 words were presented for 3 seconds each; here students were instructed to rehearse each word three times (out loud) while it was being presented. The test phase immediately followed the end of the presentation phase.

After compilation of group results, serial position curves were plotted for each condition. Based on our standard serial position curve, we developed a quantitative measure for primacy and recency. We decided that the first 6 items in the word list were involved with primacy, and the last 5 items were involved with recency (based on significant decreases and increases in the number of words recalled after the first 6 and before the last 5 words, respectively). The mean number of students who recalled words in the "primacy set" and the mean number of students who recalled words in the "recency set" were compared with the mean number of students who recalled words in the middle set (contained the middle 4 words of the list). Our measure of the primacy effect was the percentage by which the mean recall value for the primacy set exceeded the mean recall value for the middle set; our measure of the recency effect was the percentage by which the mean recall value for the recency set exceeded the mean recall value for the middle set. The quantitative primacy and recency effects obtained in this manner for the standard serial position curve were used as our baseline magnitudes for these effects, with which the results of all other test conditions were compared.

RESULTS

Our standard serial position curve (Figure 2) differed from the classically U-shaped curve (Figure 1) obtained by Capitani et al. in 1992, mainly in that our primacy effect was more pronounced, while our recency effect was not as pronounced. Our curve was also not as smooth and consistent as that of Capitani et al.. Using the previously-described quantitative measures of primacy and recency, we determined that, for the standard serial position curve, the magnitude of the primacy effect was 54% greater than the mean recall value for the middle set (i.e., 7.4 versus 4.8), while the magnitude of the recency effect was 33% greater than the mean recall value for the middle set (6.4 versus 4.8).

As expected, the long retention paradigm abolished the recency effect in the serial position curve (see Figure 3), with the mean recall value for the last 5 words (2.6) being 46% less than that of the middle set (4.8). The primacy effect was apparently abolished as well; the mean recall value for the first 6 words (4.8) was the same as that for the middle set.

Also as expected, the removal of rehearsal through the mental arithmetic paradigm resulted in a decreased recency effect in the serial position curve (see Figure 4), with the mean recall value for the last 5 words (5) being 23% less than that obtained for the middle set. The primacy effect was also decreased, with the mean recall value for the first 6 words (7.8) being only 20% greater than the mean recall value for the middle set (6.5) (i.e. the primacy effect was below the baseline magnitude). Note that the mean recall value for the middle set was higher for this condition than it was for our baseline curve.

Lastly, as expected, the controlled rehearsal condition abolished the primacy effect in the serial position curve (see Figure 5), with the mean recall value for the first 6 words (5.8) being 11% less than that obtained for the middle set (6.5). Recency was also abolished by this paradigm; the mean recall value for the last 5 words (6.4) was 1% less than that of the middle set. Note that, as in the mental arithmetic condition, the mean recall value for the middle set was higher for this condition than it was for our baseline curve.

DISCUSSION

The differences between the standard serial position curve that we obtained and that of Capitani et al. could be explained by the fact that our sample size (n=10) was significantly smaller than theirs (n=321), and thus our data was not nearly as representative of the general, normalized human serial position curve. Especially important to consider when comparing our curve with that of Capitani et al. is the fact that we performed only two group tests, and hence no statistical analysis (other than taking the mean of the results for the practice and baseline conditions). Capitani et al. were able to statistically analyze the results of 321 individual tests, and thus their curve is much more smooth than ours because they were able to "normalize away" the effects of any artifacts that appeared in their data. Despite the fact that the curve that we obtained looks slightly different from the canonical serial position curve, our standard curve does display pronounced primacy and recency effects, which, as mentioned in the Introduction, can be explained by the existence of long-term memory (LTM) and short-term memory (STM) subcomponents, respectively.

The serial position curve obtained with the long retention paradigm showed that the recency effect was abolished here, as expected. This can be explained by the fact that items cannot be maintained in STM indefinitely, if they are not operated on by some control process and transferred to LTM after a certain period of time, they are forgotten. This makes sense, especially when one considers the fact that new verbal information (e.g., words displayed or spoken on the videotape that subjects watched) is constantly entering our STM stores, even when we are not specifically trying to memorize it, and can thus displace test words from STM. It is interesting to notice that, contrary to expectations, the primacy effect was also abolished in this condition. Previous studies have indicated that the primacy effect does in fact persist over long delays, since that effect is subserved by LTM, and information that reaches LTM should certainly remain in memory across a 20-minute delay (Capitani et al., 1992). It could be that students did not sufficiently rehearse the initial set of words, and thus they were not stored in LTM after all. More likely, however, is that the quantitative measure we developed is not sensitive enough to pick up the primacy effect in this condition; by simply looking at the curve (Figure 3), it is evident that the first two words were remembered significantly more than the next four words, or even than the middle four words. If we had called only the first two words our "primacy set," then we could definitely report a primacy effect for this condition. Lastly, it should be noted that the mean recall value for the middle set of words was the same in this condition as in the standard condition. However, we would expect a decreased recall value for the middle set, since some of those middle words had probably not been transferred to LTM at the end of test, and thus their memories should not have persisted across the delay. One confounding factor that could explain this finding is that an artifact was created by the high number of students (8) recalling the 10th word (i.e., the 4th of the 4 middle words), "atom," which was a word with an unusually high emotional valence for the sample set. It could be that greater attention was paid to this word than to the other words of the middle set, and thus it may have been rehearsed or otherwise operated upon sufficiently to transfer it into LTM. This confounding factor of differing emotional valences for the various words presented probably affected every condition in our investigation. While it would be preferable to choose words of exactly the same emotional valence for every subject, so as to eliminate the effects of this factor, such a task would be difficult and time-consuming, and thus the best option is to perform many trials with a large sample size and statistically normalize one's data.

The serial position curve obtained for the mental arithmetic (no rehearsal) condition showed no recency effect, as we had expected. This effect can be explained by the fact that, with our mental arithmetic distractor task, rehearsal was prevented, and hence the last set of words was probably displaced from STM by elements of the distractor task. Interestingly, the primacy effect was decreased for this condition, when compared with baseline. We would not expect this to occur, since the words of the "primacy set" are rehearsed during the task, and have thus presumably already been transferred to LTM by the end of the presentation phase. However, it should be noted that the first two words were recalled by nearly all of the subjects, which could be considered a primacy effect, even though my quantitative measure did not detect it (see the above discussion for the long retention condition). Lastly, it should be noted that the mean recall value for the middle set in this condition (6.5) was higher than that obtained for the middle set in the standard condition. This could be explained by considering the fact that the words in this middle set may have been more visually-suggestive (or have had higher emotional valences) than those of the standard condition. It was mentioned in the Introduction that one type of control process that could be used to transfer information from STM to LTM is image formation; perhaps words that are more visually interesting are more likely to be operated on by this particular control process, and are hence more likely to be recalled.

Finally, as expected, the primacy effect was abolished in the controlled rehearsal condition. It should be pointed out, as can be seen in Figure 5, that this reduction of the primacy effect does not refer to a decrease in the number of students recalling particular words in the primacy set, but rather indicates that a similar number of students recalled words in the middle set as remembered words in the initial set (to support this, note that the mean recall value for the middle set is higher in this condition (6.5) than in the standard condition (4.8)). This can be explained by the fact that, with controlled rehearsal, a word in the middle set has the opportunity to be rehearsed an equal number of times as a word in the primacy set, and thus words from each of these sets have equal likelihoods of being transferred to LTM. This increased rehearsal opportunity, and the concomitant increased likelihood of transfer to LTM, explains the increased mean recall value for the middle set of words in this condition. Finally, it should be noted that a decreased recency effect was obtained with this paradigm. One would not expect this to be the case, since the controlled rehearsal should not affect the last set of words, which are stored in STM, other than to improve the likelihood that they will be transferred to LTM. It is possible that the subjects, who knew that this was the last test, were becoming bored and were not attending as closely to the words presented at this point in the list as they had at the start of the presentation phase. Since attention is a vitally important factor in the storage of information in any component of memory, this could explain the contradiction of our results with those we would have expected based on Atkinson's and Shiffrin's multicomponent theory.

Thus, it appears that the multicomponent theory of memory, as set forth by Atkinson and Shiffrin, does accurately predict the changes in the serial position curve that appear when a long delay in interposed between presentation and test, when a short distractor task is inserted between the two phases, and when controlled rehearsal is performed following presentation of each word. Our results did not unequivocally support this model, but the differences between what one would expect based on this model and the data that we actually obtained are better explained by factors that confounded our data than by problems with the model itself. If we had performed these tests with a larger, more diverse sample, it is quite likely that our results would have conformed to the predictions of the Atkinson and Shiffrin model; indeed, many other researchers have found this to be the case.

good job 45/45

REFERENCES

Capitani, E., Della Sala, S., Logie, R., and Spinnler, H. (1992). Recency, Primacy, and Memory: Reappraising and Standardising the Serial Position Curve. *Cortex, 28*, 315-342.

Miller, E., Frank, L., and Hohnke, C. (1997). Memory in Humans: Free Recall and the Serial Position Curve. *9.02 Course Handout.*

FIGURES

Figure 1 - Mean number of words recalled from each serial position in immediate verbal recall for a sample of 321 Italian normal subjects (Source: Capitani et al., 1992)

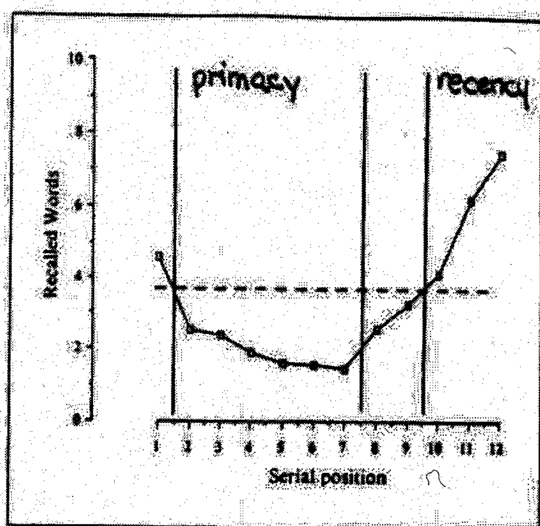

FIGURE 2 - STANDARD SERIAL POSITION CURVE

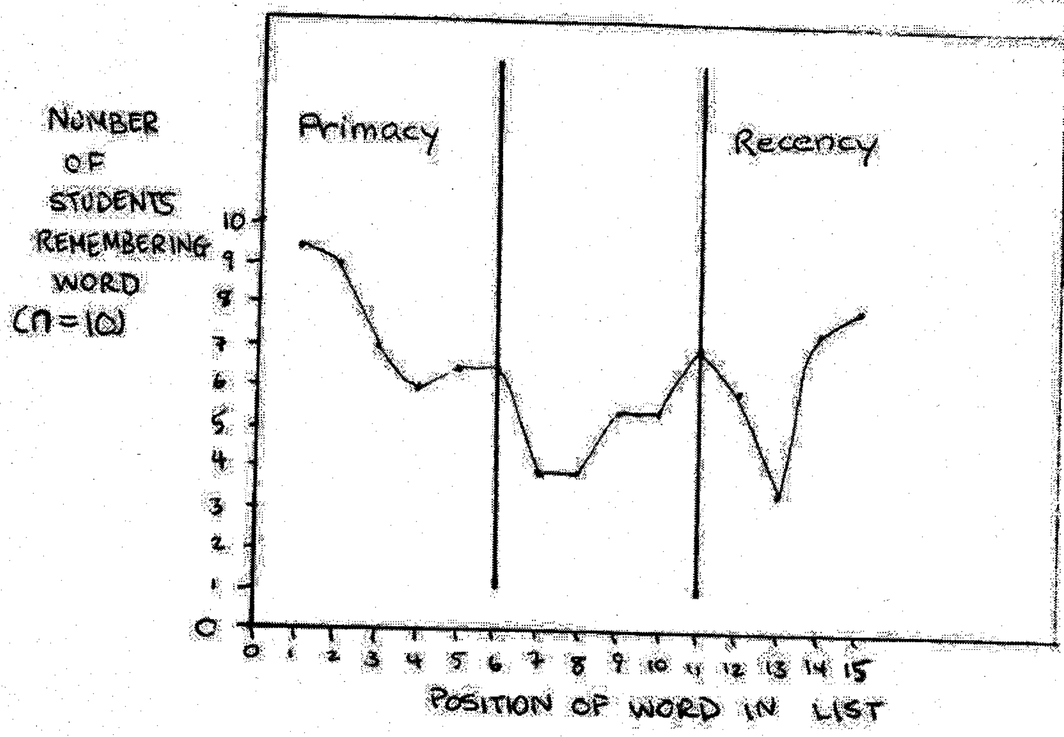

FIGURE 3 - LONG RETENTION

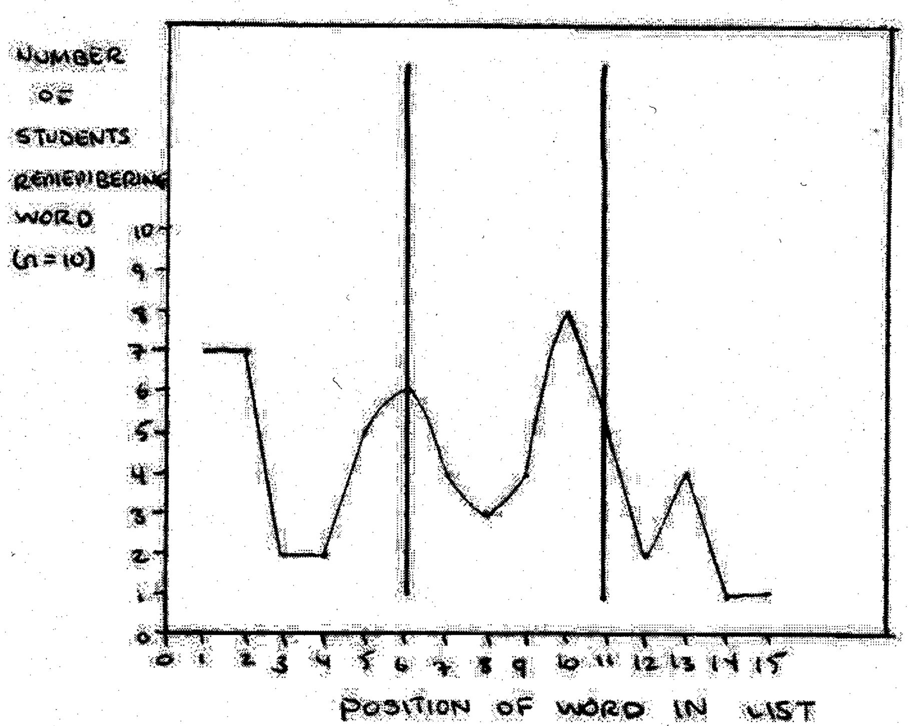

FIGURE 4 - MENTAL ARITHMETIC

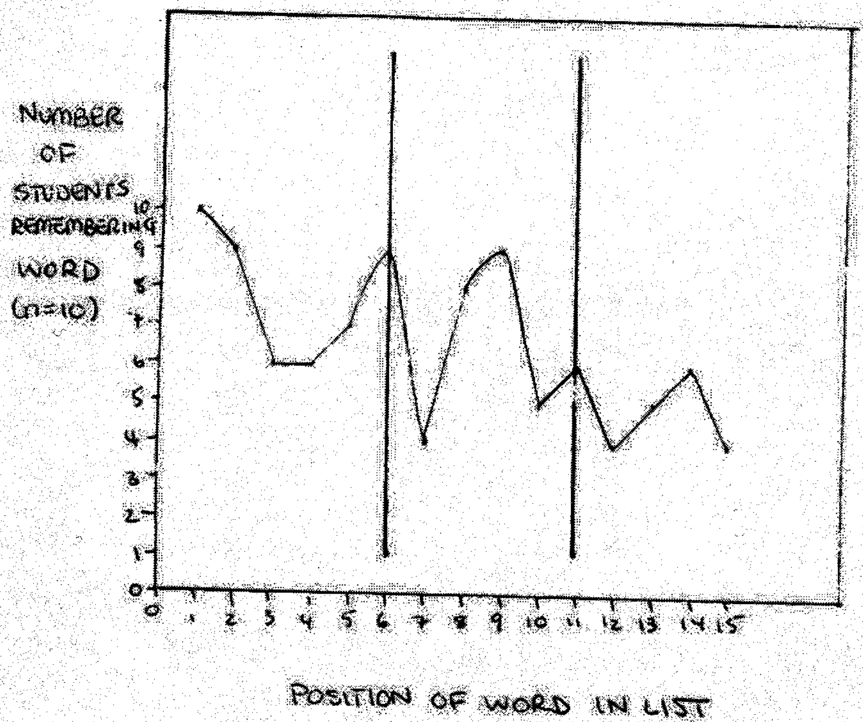

FIGURE 5 - CONTROLLED REHEARSAL