VERY LONG TERM RETENTION OF KNOWLEDGE

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Abstract

The project examined the very long term retention of knowledge which was originally acquired from formal education and which had not been subsequently used or reviewed. In higher education a great deal of time and effort is devoted to the acquisition of knowledge, but very little is known about how long this knowledge is retained. The study was designed to supply some answers to the following questions. How much of this kind of knowledge is remembered and for how long? Are some types of knowledge better remembered than others ? Does knowledge undergo structural changes over time? Do older people forget faster than young people? Is very long term retention superior when students originally obtained high grades? Do they remember it better if they found the material very interesting when they studied it? These questions have practical relevance to educational policy and practice. They also have implications for theoretical models of memory and knowledge representation.

Three different knowledge domains were investigated, cognitive psychology, experimental design and statistics, and literature. In each of these subject areas between 300-450 former students of the Open University completed a series of memory tasks designed to test retention of the course material. Approximately equal numbers of the students who were tested had studied the courses in each year between 1978 and 1989, so that the time elapsed between completing the course and the memory tests varied between 3 months and 12 years. The ages of the students at the time of testing ranged from 25 to 77 years. For cognitive psychology, the tests included recognition and recall of names, concepts, conceptual relations, general principles and specific facts. For experimental design and statistics, knowledge of principles and procedures was tested. For the literature course memory of two different classic novels was tested.

The general pattern of the results showed that rapid forgetting occurs in the first two years after learning. Thereafter memory stabilized and remained at above chance levels for the remainder of the period. Knowledge which is still retained after approximately two years appears to remain intact indefinitely. There were two exceptions to this pattern of forgetting. Although memory for details and highly specific facts declined rapidly, memory for general principles was extremely stable and showed no forgetting over the 12 year period. Similarly, knowledge of experimental design and statistics also showed no significant decline over the whole of the 12 year retention period, suggesting that active use of this knowledge in practical work made it more memorable, and possibly reflecting a superior retention of procedural, as opposed to declarative, knowledge.

The effects of age were slight. The elderly students had poorer memory for specific facts, but in the other tests elderly students generally remembered as well as young students. The rate of forgetting was the same for young and old, so there was no indication that elderly people forget what they have learned more quickly. Another finding of major importance concerns the extent to which good retention is associated with high grades. When grades were decomposed into examination marks and course work marks it was found that high course work marks were associated with good retention but examination marks were unrelated to retention. The findings were related to theoretical models of memory and pedagogical implications were pointed out.

Introduction

During the process of education many topics are learned in considerable detail, some even to expert levels, but subsequently much of this knowledge is never reviewed and remains wholly unused. What is the fate of such knowledge? Is it rapidly forgotten? Is it selectively forgotten with, for instance, the details being lost first and more general aspects being retained for longer? Does the initial depth of learning determine the period of retention? Is retention affected by aging? For example, do elderly students forget more rapidly?

In spite of their obvious importance, these questions have been almost totally neglected until very recently. Theories of memory have been based on retention tested after very short periods seldom exceeding half an hour. And, although the value of inculcating knowledge must surely depend on it being retained in memory, educational policy and curicula have been formulated without regard to these questions. It is also important for re-training schemes to be able to estimate how much knowledge is likely to be retained from previous training.

The first attempt to address issues about the very long term retention of formally acquired knowledge was reported by Harry Bahrick in 1984. He studied the retention of Spanish learned in high school and not used or rehearsed afterwards. Retention was tested after intervals ranging up to 50 years. He found a strong relationship between retention and the initial depth of learning which was assessed on the basis of the number of courses taken and grades achieved. When retention was plotted against time elapsed the resulting retention curve was discontinuous with three distinct segments. There was rapid forgetting in the first five years; retention then stabilized and remained at the same level for about 35 years: this stable period was followed by a down turn with a further decline in the final period.

Bahrick's findings were of great interest but left numerous questions unanswered. He had tested only one knowledge domain (Spanish) so that it was not clear how far his results would generalize to other knowledge domains. Moreover, he had tested only the amount of knowledge retained so that his study yielded no information about whether knowledge structures change over time. Finally, there was controversy about the interpretation of the retention function. Bahrick argued that, with sufficient depth of initial learning, knowledge is transformed into a more stable and permanent form (called the "permastore") which is reflected in the long period of stable retention from 6-35 years shown in the retention curve. This interpretation was challenged by Neisser (1984). He argued that specific knowledge is forgotten, but general knowledge schemas are retained which allow some of the original knowledge to be reconstructed. The resulting controversy was not resolved. In addition, the interpretation of the accelerated decline in retention which occurred after 40-50 years was also ambiguous. Because the original learning took place when the students were in their late teens, the data from this down turn portion of the retention curve was drawn from subjects who were then 60-70 years old. Deficits in memory typically begin to be apparent at this age, so it was therefore impossible to decide whether the final decline in retention was due to the effects of aging or to the length of time elapsed since the original learning.

Our study was designed to extend the study of very long term retention of knowledge to different knowledge domains and to address some of issues that had not been resolved by Bahrick's work. Our research has been conducted using Open University students as subjects and studying their retention of material from Open University degree courses. This has a number of unique and very important advantages. Firstly, the courses are highly structured and the material is presented and taught in a uniform and standardized way. The students are objectively and formally tested by both course work assignments and an examination, and records of their grades are available. Secondly, the students' ages range from 21 to 80+. This means that the effects of age on retention can be studied and separated out from the effects of retention interval.

Our research comprises two separate studies as described below.

I. **Very long term retention of cognitive psychology, including experimental design and statistics.**

The study was based on data from 373 Open University students who took an undergraduate course in cognitive psychology between 1978 and 1989. The course included perception, memory, language and problem solving. Experimental design and statistics were taught as part of the course and used in practical work and projects. Approximately half the subjects were volunteers who responded to personal contact or advertisements in a student newspaper. The remainder were traced through student records and contacted by mail or telephone. Cold mailing produced a poor response rate of 44%, but for students who were telephoned and agreed to take part in the study the response rate was 90%. The age range was between 25 and 72 at the time of studying the course and for the analyses they were divided into three age groups, a young group aged 25-40 (n=104); a middle-aged group aged 41-60 (n=196) and an elderly group aged 61-77 (n=73). The retention interval (RI) was defined as the time elapsing between taking the final examination and being tested in our study. Approximately equal numbers of subjects were drawn from each of 12 retention intervals which ranged from 3 months (the shortest RI) to 125 months (the longest RI)

Subjects were sent a pack consisting of a letter, a questionnaire, and a set of test materials. The letter stressed that tests should be completed in the designated order; that subjects could take as much time as they liked, but that on no account should they review any of the course texts or related material as this would invalidate the study. The letter also assured them that their responses were valuable even if they remembered very little. All subjects completed a questionnaire before beginning the memory tests. In this they were asked to state the year they took the course, their age at that time, and the grade they achieved. They were also asked to give a rating on a scale of 1-3 (1=not interesting; 2=fairly interesting; 3=very interesting) of their interest in each area of the course. Finally, they were asked to describe any further contacts they had had with the cognitive psychology since completing the course and types of contact were classified and coded. Those who had continued to work in the field or in related areas were excluded from the study. Other forms of contact consisted of reading articles in magazines or newspapers and watching television programmes. It was judged that these were highly unlikely to reinstate the very specialized knowledge tested in this study and initial analyses confirmed that the levels of contact recorded had no effect on retention.

Possible criticisms of this procedure are as follows:-
(1) It is impossible to be sure that some self-selection did not take place such that weaker students and those who thought they remembered very little opted not to take part. However, the original grades and the test scores indicated that the lower end of both ranges was well represented.
(2) We cannot guarantee that subjects did not cheat by looking up the answers. However, if a subject did cheat we would expect to find untypically high scores outside the normal distribution for that RI and no such instances were found. Moreover, the accompanying letter stressed that looking up answers would invalidate the study.
(3) It was impossible to ensure that all ages were equally represented at each RI. Inevitably, there were fewer older subjects at the shorter RIs and more at the longer RIs, but this imbalance was corrected for in the statistical analyses.

We devised a set of tests designed to measure knowledge retention in a variety of different ways and to cover the full range of course material. Extensive pilot testing was undertaken to establish the appropriate level of difficulty for the tests. The tests were also given to a control group of subjects who had never studied cognitive psychology in order to establish guessing levels of responding. All the subjects completed all the tests.
The **Recognition Tests** consisted of two lists, one list of 16 target names of psychologists drawn from the course material mixed with 16 foil names drawn from the telephone directory, and one list of 16 psychological concepts from the course mixed with 16 foils which were plausible but fabricated concepts. Students had to identify those names and concepts which had occurred in the course.

The **Fact Verification Tests** consisted of 24 factual statements which students had to classify as true or false. Half the statements were of *general* facts: that is, they were high level statements about general principles, models, theories or definitions of key terms. Half the statements were of *specific* facts: that is, they were lower level statements about details of findings.
The **Grouping Test** explored memory for conceptual relations. A list of 24 concepts was supplied. Although they were scrambled in the list the concepts were actually related so that they were drawn from six different conceptual groups, and the students' task was to sort them into the correct groups.
The **Cued Recall Test** examined the ability to recall specific names and concepts. The test consisted of 12 statements with missing words. Half of the missing words were names (e.g. *E----- was a German psychologist who studied the learning of nonsense syllables*) and half were concepts (e.g. *Tulving distinguished between e----- memory and semantic memory*). The students were asked to fill in the missing words, but the first letter of each missing word was supplied because pilot testing showed that the test was too difficult with just blanks.
The **Experimental Design Test** examined memory for experimental design and statistics. This was a multiple choice test in which 20 statements had two alternative endings (e.g. *Parametric tests assume that scores in the experimental conditions show (a) homogeneity of variance (b) heterogeneity of variance*). The students' task was to select the correct alternative.

In all the tests the students were asked to give a confidence rating on a scale of 3-1 (3 = very sure, 2 = fairly sure, 1 = guessing) for each response.

The effects of retention interval: These effects are shown by the slope of the forgetting function when scores are plotted for increasing retention intervals as in the example shown in Figure 1. In assessing the effects of the length of time elapsed since study the different tests have to be considered separately. This is because they differ in format, in level of difficulty and in the level of performance that could be achieved by pure guessing. Separate analyses of variance were therefore performed for each of the tests. The effects of retention interval, grouped into six intervals, were significant for name recognition; for concept recognition; for fact verification specific; for grouping; for cued recall of names and for cued recall of concepts. The effects of retention interval were not significant in the tests for fact verification general or in the test of experimental design. It can be seen, therefore, that the nature of the retention function varies with the type of knowledge being tested. Hierarchical regression analyses showed that Grade, Interest and RI were all significant predictors of retention.

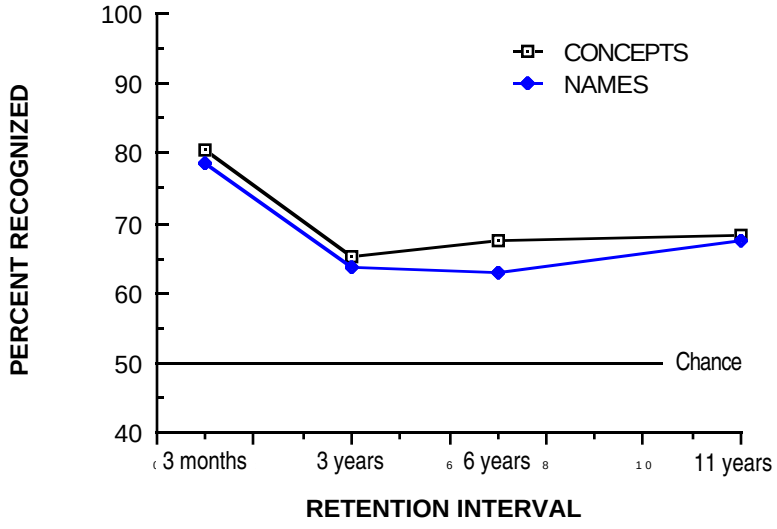

Figure 1. Percentages of correct responses to names and concepts in the recognition test.

Figure 1 illustrates in a simplified form the type of retention functions obtained in the recognition tests. Scores at the three month retention interval averaged 80%. It cannot be assumed that 20% of knowledge has been lost in three months because students would certainly not have been at the 100% level when they finished the course. This 20% decrement reflects both knowledge that was never acquired and knowledge that has been forgotten since the end of the course. Moreover, performance at the 80% level has to be seen in relation to the chance level of performance which, in this particular test, was 50%, so that students were performing at 30% above chance. Three years after completing the course, retention has dropped to 65% showing that a further 15% has been lost. Scores then persist at close to this level so that at the longest retention interval of 11 years, scores were still averaging close to 65%. Note, however, that this pattern of results does *not* mean that students achieve 50% by guessing and are only remembering 15%. Although they *could* have achieved 50% by guessing, their confidence ratings showed that at the shortest retention intervals students were sure of the answers and even at the longest retention intervals confidence was well above the guessing level.

In the fact verification test scores initially averaged around 70%. Memory for specific facts declined to 65% after three years and then stabilized. However, memory for general facts showed no significant effects of retention interval. High level knowledge about general principles appears, therefore, to be more resistant to forgetting than memory for lower level specific details.

Memory for conceptual relationships, as revealed by the grouping test, is more fragile. Scores declined quite steeply from 57% to 34% over the first three years before levelling out. In the cued recall test, ability to recall the missing names and concepts averaged around 58% after 3 months. For names, scores had dropped to 23% after two years, whereas concepts were lost more slowly reaching 30% after three years, and stabilizing after that. Unlike the other tests, where scores may be inflated by lucky guesses, the cued recall test is a pure test of memory since it is essentially impossible to give correct answers by guessing. There were big differences between individual students on this test and the proportion of students scoring zero increased steadily from 8.5% in the first few years to almost 30% after 11 years.

Performance in the test for experimental design and statistics was surprisingly robust. Starting at 76% (26% above chance) at the shortest retention interval, there was no evidence for any significant amount of forgetting over the 11 year period.

The findings can be summarized as follows. Memory for general facts showed no forgetting. In contrast, memory for specific facts, names, concepts and conceptual relations showed rapid forgetting in the first two to three years but then stabilized and remained at an above chance level. After 11 years people had forgotten between 15 to 30% of what they knew three months after completing the course. The difference in the patterns of retention for general and specific information is particularly interesting. Memory for general facts involves understanding. That is, this kind of knowledge is deeply embedded in high level knowledge schemas. Specific details are represented at a lower level in the general schema and are less integrated with related knowledge. This is especially true of names. Names are arbitrary and have few semantic associates. Although imagery mnemonics may sometimes be used, names are commonly learnt by rote. The differential forgetting functions for general and specific information may therefore be reflecting a difference between understanding and rote learning as well as a difference between higher level and lower level knowledge.

The findings showed that knowledge of experimental design and statistics is also resistant to forgetting. This finding offers support for the views expressed by Gale (1990) in which he stressed the value of practical work in producing psychologists. Students on our course were required to use their knowledge of experimental design and statistics in projects and experiments which they carried out themselves. Many students found this aspect of the course difficult, but they needed to achieve a minimal level of competence in order to complete the course assignments. The findings suggest that practical course work in which knowledge is actively put to use serves to 'fix' that knowledge effectively.

The effects of grade and interest: Multiple regression analyses of the data showed that the final grade awarded for the course was a significant predictor of retention. People who achieved higher final grades showed better retention than those who had poorer grades in all the tests. Figure 2 shows the relationship between grade and performance in the cued recall tests and this relationship was similar in the other tests.

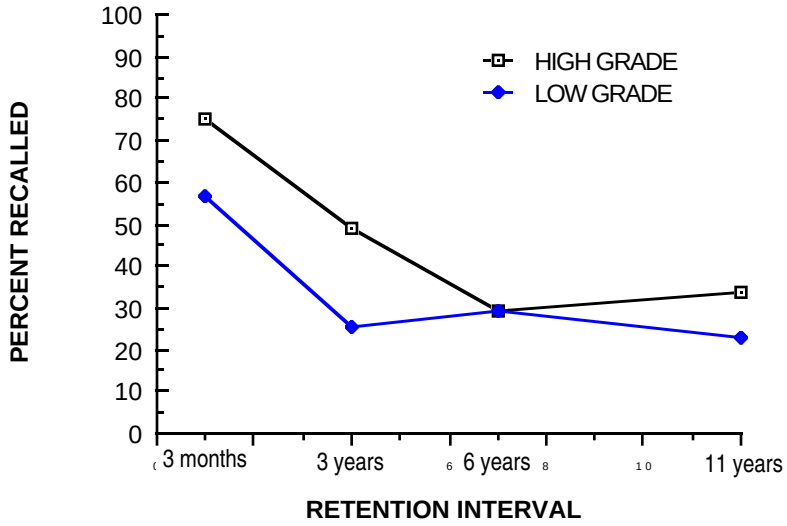

Figure 2. Scores of students with high and low grades in the test for cued recall of concepts.

However, the final grade was calculated on the basis of both the grade for the written examination and the grade awarded for course work. When these two elements were decomposed and entered into the analyses separately it was apparent that the grade for course work was a much more powerful predictor of performance. People who did good work for their essays and projects remembered the knowledge they had acquired much better than those who did poor work. By contrast, the grade for the written examination was weakly associated with performance in only one of the five tests (the grouping test) and was not associated at all with scores on the other tests. The rated level of interest in the course was also a significant predictor of performance. People remembered information better and longer if they found it interesting.

The effects of age: One of the aims of our research was to compare the performance of elderly students with that of younger age groups. Laboratory tests consistently show that some aspects of memory are impaired by aging. However, in everyday situations where they are highly motivated and can work at their own pace, many elderly people continue to perform as well as the young. An in-house Open University research project (Clennell,1987) comparing the performance of 3000 students aged over 60 with 74000 aged under 60 showed that, although the older group did slightly less well in written exams, they actually did better on course work assignments. Our own research showed that elderly students of cognitive psychology did less well on only two of the tests. In verification of specific facts the main effect of age was significant and there was a marginally significant effect of age in cued recall of concepts. In all the other tests there was no effect of age and in no test was there any indication that elderly people forget what they have learned more quickly than younger people. The slopes of the forgetting functions were the same for young and old.

Because the intercorrelation of age and RI raises problems for the statistical analyses further analyses were undertaken using matched subgroups. Thirty-one subjects aged over 65 were compared with 31 subjects under 40. The two subgroups were matched for RI and for Grade so that these factors would not be reflected in group differences. Analyses of measures of sensitivity and response bias showed that overall, there were no differences in sensitivity but the elderly had a more liberal response bias than the young group. That is, they had a lower

criterion for responding 'Yes' or 'True' to items in the recognition tests. This bias results in an increase in false positive errors. No other age differences were found.

There are two reasons for the lack of any marked effects of age. Firstly, it must be remembered that elderly people who choose to study a demanding degree level course are not a representative sample of the elderly population. They are likely to be highly intelligent, well motivated and fairly confident in their own ability. It is well established, as Patrick Rabbitt of the University of Manchester has repeatedly shown, (e.g. 1988) that the high IQ elderly are less likely to show age-related memory impairments. Secondly, the results conform to the theoretical model of Dixon and Baltes (1986) who distinguish between the fluid 'mechanics of intelligence' which refers to cognitive operations, and which is affected by aging, and the crystallized 'pragmatics of intelligence' which concerns factual knowledge and which resists the effects of aging. It is exactly this kind of crystallized knowledge which was tested in our study. The results give encouraging evidence of the ability of older students to pursue and profit from higher education. For further details, see Cohen, Stanhope and Conway (1992a).

Theoretical implications of the study

The findings were related to the permastore versus schema theories of very long term retention put forward by Bahrick and Neisser respectively. The superior retention of high level knowledge provided support for the schema interpretation, but other findings, such as the fact that a substantial amount of specific and detailed knowledge is remembered, were inconsistent with the view that only schematic knowledge is retained. Information such as names cannot be reconstructed from schemas. Although our results showed that names were remembered less well than concepts, memory for names persisted well above chance up to the longest retention interval. Overall, therefore, our results provide evidence that schematic knowledge is retained better, but that some non-schematic specific knowledge is also retained, as Bahrick claimed, in a way that is resistant to further forgetting. The fact that, at longer retention intervals, performance actually exceeded levels of confidence suggests that the distinction between explicit and implicit memory is important with very long term memories becoming more and more implicit.

Practical Implications of the study

(1) The importance of course work, rather than examinations, as a determinant of subsequent long term retention of the material.
(2) The importance of arousing the students' interest since poor retention is shown to be associated with lack of interest.
(3) The finding that knowledge is retained particularly well when it is actively employed in practical work.
(4) The finding that elderly students are not necessarily disadvantaged and that the effects of aging can be offset by interest and ability.
This study is reported in Conway, Cohen and Stanhope (1991) and in Cohen, Stanhope and Conway (1992b).

2. Very long term retention of classic novels

For our second study we elected to explore a very different type of knowledge domain, the knowledge acquired from study of a novel. Although recent years have produced a vast amount of research on memory for short texts and brief stories these rarely exceed 200-300 words, and the retention interval between study and test is also very short, usually not more than half an hour. Our study breaks new ground in examining very long term memory for a whole book.

There are therefore two main issues in this study. Firstly, we wanted to discover whether the patterns of retention evident in very long term memory for cognitive psychology and Spanish would generalize to the very different knowledge domain of literature. Secondly, we wanted to establish whether the findings about memory for very short simple stories would hold good for complex full-length novels. Hierarchical models have been developed to characterize memory

for short stories and one of the aims of the present study was to discover whether memory for a full-length novel is also represented hierarchically.

The subjects were Open University students who had studied a general arts course which included detailed study of a classic novel. Unfortunately the particular novel was changed part way through the period of our study. From 1978 to 1986 the set novel was Jane Eyre by Charlotte Bronte. From 1987 to 1990 the novel was Hard Times by Charles Dickens. Thus the retention intervals for Hard Times ranged from 3 months to 39 months and for Jane Eyre from 40 months to 136 months. Because the two novels are very different in content and structure and because the retention periods are different it was necessary to treat each as a separate study.

Memory for Hard Times

Subjects were again recruited by advertisement in a student newspaper. 152 were selected so as to yield approximately equal numbers in each retention interval and each age group. 140 people (92%) completed and returned all the tests. As in the study of cognitive psychology, subjects were sent a pack with a letter of explanation, questionnaire and a set of tests. The tests were devised and piloted and, as before, guessing levels of responding were established by testing a control group who had never read the novel.

The first task asked subjects to briefly describe their most striking memory from the novel. Story-grammar models predict that components of a story which are at superordinate levels of the story hierarchy will be better remembered than subordinate level elements. It was predicted therefore that superordinate elements would predominate.

The second test required free recall of the names and roles of characters in the novel. We predicted that roles would be recalled relatively better than names. If story schemas are retained, memory for roles should be superior to memory for names. This is because the roles of the characters are related logically and semantically to the story schema and so can be inferentially reconstructed from the schema, whereas names are arbitrary and cannot be inferred.

The third test was fact verification. Subjects were asked to make true/false judgements about 54 events and facts drawn from three different hierarchical levels. Superordinate statements were important, salient and central to the plot; subordinate statements concerned unimportant details that were peripheral to the plot, and there was also an intermediate level.

The responses in the 'most striking memory' test fell clearly into four story-grammar categories. There were two superordinate categories (setting and theme) and two subordinate categories (episodes and characters). Statistical analysis showed a clear preponderance of the superordinate memories. The names and roles test showed that, as predicted, roles were remembered better than names. There were significant effects of retention interval but forgetting levelled off by 27 months and there was no further decline in memory after that. Approximately 20% of names and 35% of roles were still remembered after 39 months. Memory for names started to decline earlier than memory for roles and was lost more rapidly. The results of the fact verification test clearly confirmed the hierarchical structure of the memory representation. Superordinate events/facts were remembered better than intermediate level ones and these were remembered better than those from the subordinate level. After 3 months, scores were 40%, 30% and 14% for the high, medium and low levels respectively. However, although memory for high and medium level events declined with retention interval up to 27 months and then stabilized, memory for low level events was uniformly poor but did not decline further. Regression analyses showed that scores were significantly related to grade and to RI but there were no effects of interest, age or gender.

These results, in spite of the difference in knowledge domain, are broadly similar to those obtained in the study of cognitive psychology. There is a rapid initial decline in memory followed by stabilization of the residual knowledge. Superior recall of roles relative to names and of high level events relative to lower level events supports the view that schematic knowledge is better retained but, again, there is evidence for above chance long term retention

of some low level non-schematic knowledge. A detailed account of this study is given in Stanhope, Cohen and Conway (in press).

Memory for Jane Eyre

The design and procedure for this study was very similar. Five hundred volunteers were selected to give approximately equal numbers at each RI. Four hundred and fifty (90%) completed all the tests. The independent variables were RI, age, grade, interest and gender. Subjects were asked to describe any contact they had with the novel after completing the course. Although in the case of Hard Times subsequent contact was minimal, a considerable number of subjects had re-read Jane Eyre, seen it on film or television or heard a radio version. These different forms of contact were coded and weighted for recency and entered into the regression analyses as an independent variable.

The design of the tests differed from those used in Hard Times. For example, characters in this novel are too numerous for a recall test to be feasible so a recognition test was substituted. The tests were as follows:-
(1) Name recognition: there were 26 pairs consisting of a character's name and a foil name. Subjects had to select the name which had appeared in the novel.
(2) Role recall: Subjects had to recall the role of each of the 26 characters.
(3) There are four distinct locations in the novel. Each character is associated with one location and subjects had to select the correct location for each character.
(4) Fact Verification: Subjects had to make true/false judgements about 60 events/facts drawn from superordinate, intermediate and subordinate levels in the hierarchy.

In this study the shortest retention interval sampled was 40 months. The results indicated that memory had stabilized by this time as there was very little evidence of memory decline within the period tested. Both roles and locations were remembered better than names, a finding which is again consistent with schema-based memory. The fact verification test yielded results similar to those obtained in the study of Hard Times with a pronounced levels effect. A triple interaction of RI with the level and the truth/falsity of the statement showed that as time elapsed there was an increased tendency to respond 'true' to false statements especially in the case of low-level items. Regression analyses showed no effects of RI. As in the previous study performance was unrelated to exam score but was significantly associated with the grade awarded to a course work essay about the novel. However, both age and gender were significant predictors of performance and also of confidence. The middle-aged group were superior to the young and elderly groups which did not differ from each other and female subjects had higher scores than males. However, middle-aged females rated their interest in the book more highly than other groups and also had more subsequent contact. In the case of Hard Times there were no gender differences in interest or contact and no gender effects were observed in the memory tests. We concluded therefore that factors correlating with gender were affecting memory for Jane Eyre rather than gender itself.

Theoretical implications and conclusions

The two studies of very long term retention of novels, taken together, exhibit the same pattern of retention seen in cognitive psychology and in Bahrick's studies. There is a rapid decline in the first two or three years followed by a long stable period. This pattern appears to generalize across very different knowledge domains. There is evidence to support Neissser's view that knowledge schemas are well retained and that knowledge which can be reconstructed from a schema is more likely to be recalled. On the other hand, we found evidence that some knowledge which is not schema-based, such as names and low-level peripheral details, is retained for long periods of time suggesting that some form of permastore is also operating. The absence of a significant age decrement in our research suggests that the final decline in Bahrick's retention function is unlikely to be due to aging. This research showed very clearly that memory for a complex full-length novel is organized in an hierarchical manner in the same way as memory for a short text and that this organization persists over a long time. The replicated finding that course work grade, but not exam grade, predicts long term retention is

consistent with theories of memory in which active and elaborative processing produces better recall than rote learning.

This study illustrates the advantages and disadvantages of so-called 'natural experiments'. When data is obtained from naturally occurring learning situations the results are obviously much more relevant to educational practice. However, such data is not always as neatly standardized as is desirable. Here we were obliged to contend with the change of novel part way through the retention period, but this problem produced some compensations. For example, it enabled us to see that the hierarchical organization of memory was found in exactly the same way for both novels in spite of the fact that they are very differently structured.

Further research examining different knowledge domains is currently being planned.

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