Effects of Lecture Information Density On Medical Student Achievement

I. Jon Russell, M.D., Ph.D., William D. Hendricson, and Robert J. Herbert

Abstract—With the virtual explosion of biomedical information, the medical educator regularly faces a quandary regarding how much to include in the medical curriculum. Opinions differ regarding how much of the available information on a particular topic should be presented in a medical school lecture. To understand better the effect of lecture information density on learning by medical students, one of the authors gave a basic clinical lecture only or clinical lectures with varying amounts of semirelated information. Tests which measured only retention of the basic material were given before lecture attendance, immediately after the lecture, and 15 days later. The results indicated that increasing the information density of a lecture reduced retention of the basic information. The memory loss apparently was due to information presented late in the lecture displacing facts learned by the students earlier in the same hour. The data suggest that lectures to medical students are more effective aids to learning when the information density is limited to a few main points that are "essential to know."

It is widely acknowledged that the volume of material introduced in medical school lectures and textbooks is so great that it probably exceeds the students' capacity to memorize and integrate it (1). After examining curricula and textbooks in Great Britain's medical schools, Anderson and Graham (2) estimated that medical students are expected to learn approximately 48,000 facts and nearly 30,000 concepts during their two years of basic science training and roughly 53,000 facts and concepts during the clinical phase. Assuming this is true, medical students must learn about 24 new facts/concepts per hour as underclassmen and 13 facts/concepts each hour in their two clinical years. By comparison, it was estimated by the same authors that students in fine arts and mathematics programs are expected to learn only 6 to 10 concepts/facts per hour.

Medical students are not alone in their attempts to cope with information overload. Today a common phenomenon is the harried instructor racing through his lecture at a breathless pace in an effort to cover the "salient" material. This exercise often leaves the instructor drained and the students frustrated. The information density problem in medical schools is

Dr. Russell is assistant professor of medicine, Division of Clinical Immunology, and Mr. Hendricson is an educational specialist and Mr. Herbert is senior research assistant, Division of Instructional Development, all at the University of Texas Health Science Center at San Antonio.

being compounded annually as the biomedical literature expands. For example, in 1961 the Science Citation Index listed 603 refereed biomedical journals containing 102,000 original articles. By 1981 that number of journals had risen to 3,000 with over 700,000 articles (3). Well-intentioned instructors feel obligated to incorporate new discoveries into their lectures but have difficulty eliminating content previously included. This process leads to an increasingly dense curriculum as more and more material is presented without a corresponding expansion in curriculum time.

The lecture remains the most popular teaching method in medical school despite criticisms of its effectiveness. In conjunction with textbooks, it is the primary mechanism for communication of biomedical knowledge to students. Previous studies of lecture techniques have identified several factors which influence retention. These include: (*a*) the type of note-taking strategy utilized by the student, particularly the students' ability to conceptualize the instructors' words and transcribe them in a personally meaningful way (4, 5); (*b*) the lecturers' rate of speech (4); (*c*) the use of visual aids (6, 7); (*d*) the charisma or enthusiasm of the speaker (8); (*e*) the time within the lecture when information is presented (5, 6); and (*f*) the alertness of the audience (9).

Another variable which may affect retention of lecture material is information density. This factor has been discussed extensively in the literature but has been the subject of only limited research. Aiken (10) defined information density as the percentage of sentences in the presentation which communicate new principles and facts not previously known to the student.

The average rate of speech in a lecture is about 100 words or approximately four sentences per minute. In a high density presentation, most of these sentences (for example, 80 percent) introduce new concepts or facts. In a low density lecture, 50 percent or less of the sentences introduce new information. During the remaining time, the lecturer uses reinforcement strategies such as restating key ideas, highlighting the material's significance, presenting examples, and comparing the new information with the audience's prior experiences.

Students tend to retain high levels of learned material only briefly unless the information is frequently reviewed or applied (4). For many years, educational psychologists have advocated use of the low density lecture strategy, claiming that it fosters more efficient learning (10, 11). The studies of Aiken and colleagues (10) supported that contention, but they were conducted under highly artificial conditions. The following prospective, single-blind study was designed to evaluate the impact of lecture density on retention of key concepts presented to medical students in their usual classroom setting.

Methods

Three versions of a 50-minute lecture on fibrositis syndrome were developed for presentation to junior medical students during an internal medicine clerkship at the University of Texas Medical School at San Antonio. They were designed to provide high, medium, and low information density profiles. The low density lecture included only the basic information necessary for students to achieve the learning objectives of the course. The remainder of the time was spent in elaboration of the main points, reemphasis of prior concepts, and periodic summarization. The medium density lecture was prepared by deleting about 10 minutes of reinforcement material from various

TABLE 1

Number of Minutes Used To Present New Information and To Reinforce Information in Three Different 50-Minute Types of Lectures on Fibrositis Syndrome Given to Junior Medical Students, University of Texas Medical School at San Antonio, 1983

Lecture Type*	Soft Tissue Rheumatism	Historical Perspective	Clinical Presentation	Secondary Causes	Primary Causes	Treatment Methods	Total
High Density							
New information	9	5	9	8	10	4	45
Reinforcement	1	0	1	0	2	1	5
Medium Density							
New information	0	4	9	8	10	4	35
Reinforcement	0	0	6	0	2	7	15
Low Density							
New information	0	0	9	4	9	3	25
Reinforcement	0	0	9	0	9	7	25

* For definitions, see text.

points throughout the lecture and replacing it at the beginning of the lecture with new information from a related presentation on soft tissue rheumatism (Table 1). The high density lecture was prepared in a similar manner with the "essential to know" information being presented in 30 minutes and the remaining 20 minutes (primarily at the beginning) being devoted to new material on soft tissue rheumatism. Thus, each group was given the basic information on fibrositis syndrome from which all the test questions were derived, but the medium and high density lectures contained increasingly more conceptual/factual information, respectively.

The same instructor (I.J.R.) presented each version of the lecture in order to reduce the likelihood that a difference in lecture style would affect the degree of retention. All information related to the objectives was presented in the same sequence in all three lectures. The same slides were used in each lecture to visually reinforce material designated as essential-to-know. In the medium and high density lectures, additional slides were used to illustrate the additional new information presented. A verbatim transcript of each lecture was taken from an audiotape recorded when the lecture was presented. For example, in the following excerpt taken from a verbatim transcription, the six sentences in parentheses presented data which were unfamiliar to students who had not yet encountered a patient with fibrositis syndrome.

> 1. Perhaps I can best describe the syndrome by picturing the characteristic patient. 2. (Typically it's a middle-aged female who presents at the physician's office in a rather distraught state but who does not really appear chronically ill. 3. She complains of severe pain all over her body which has been bothering her for several months.) 4. The patient's subjective complaints and the clinical profile are presented on this slide. 5. First, the subjective findings: (Patients volunteer that they sleep poorly, and many report having a poor appetite. 6. They experience morning stiffness and a weather-related effect similar to that seen in rheumatoid arthritis. 7. Most of these patients are troubled by emotional distress or worry, often regarding a domestic problem.) 8. An example might be a wife in her 40s who is concerned that her husband is becoming more interested in other women and less attentive to her. 9. Yet, she is afraid to confront him with her fears because she is financially dependent on him. 10. (On examination, these patients have reproducible tenderness to palpation at very predictable locations near peripheral joints, yet they have unrestricted joint motion, suggesting that

the cause of the problem is not true arthritis.)

Using these transcripts, it was determined that 180 sentences (90 percent) of the high density lecture were devoted to dissemination of new information (Table 1). The relative distribution of time spent on each subtopic was estimated by dividing the number of sentences devoted to each area by the average of four sentences per minute. (For example, the new information on soft tissue rheumatism in the high density lecture was 36 sentences divided by four sentences/minute = nine minutes.) By comparison, only 70 percent of the medium and 50 percent of the low density lecture hours contained new information. The density (units per hour) of new information in each lecture was estimated by dividing the observed number of sentences per lecture which contained new information by three hours of student study time (based on the traditional measure of one hour in class and two hours out of class) for that lecture (2). This calculation resulted in a new information density of 60 units per hour for the high density lecture, 46.6 units per hour for the medium density lecture, and 33.3 units per hour for the low density lecture.

A total of 123 students were randomly distributed into the three lecture groups. An analysis of variance indicated that there was no significant difference in the cumulative medical school grade-point average among the high, medium, and low density groups ($F[2,117]=1.561$; $p = .241$).

All three groups received the same type of handout to guide note-taking. These lecture notes utilized the partial handout format (5) that provided the objectives, a detailed outline of the subject matter, relevant tables, selected figures, and ample space for writing. The handouts given to the students in the high density and medium density groups were longer than the handout given to the low density group, reflecting the additional information presented to the former groups.

Students in all three groups completed the same 16-item, multiple-choice pretest to assess their knowledge of the subject prior to the lecture. Immediately after the lecture, they completed the same test (posttest 1) to assess short-term retention. A second posttest (posttest 2) containing the same items was administered without prior warning approximately 15 days later to measure long-term retention. The study test was constructed by selecting from a test-item pool questions pertaining to essential points from the low density lecture, and several questions for each learning objective were included. The questions were field-tested by 100 junior medical students not involved in the study. An analysis of their performance led to revision of the few test items with construction problems. Test reliability was analyzed by the modified Kuder-Richardson formula no. 20 using Horst's modification (12). Reliability coefficients for several administrations during field-testing ranged from .47 to .59. During the investigation, reliability coefficients for the achievement tests administered to the three study groups ranged from .60 to .67. The investigators considered these levels to be acceptable given the brevity of the test.

For purposes of statistical analysis, the independent variables were lecture density (high, medium, and low) and time of achievement test (pretest, posttest 1, and posttest 2), while the dependent variable was student performance on the achievement tests. A two-way analysis of variance (ANOVA) was utilized to determine whether the effects of the independent variables were statistically significant. To

identify significant differences among the lecture density groups and to determine whether the differences in group means matched expected patterns, one-way ANOVAs were then computed and Scheffe's Test of Multiple Comparisons (13) was used for posthoc analyses. Posttest 1 and 2 performances of the three groups on questions keyed to the time within the lecture when relevant data were presented were analyzed as follows. Learning gains within each group between the pretest and the two posttests were assessed by a repeated measures ANOVA. Paired *t*-tests were used for the posthoc comparisons. Comparisons between groups were evaluated by one-way ANOVAs, and grouped *t*-tests were used for the posthoc comparisons.

Results

Data analysis addressed two questions. Was there any difference in short-term and/or long-term retention of presented information among students attending the high, medium, and low density lectures? Was there any difference in the level of attentiveness (as measured by test performance) among the three groups for the initial 15 minutes, middle 20 minutes, and final 15 minutes of the lecture?

All 123 students completed the pretest prior to the lecture. Of those, 120 attended one of the three lectures and completed posttest 1, while 106 also completed posttest 2. All participants were volunteers. The attrition between the pretest and posttest 2 was due to absenteeism.

A one-way ANOVA revealed no significant differences among the groups on the pretest ($F[2,120]=.824$; $p = .441$). Therefore, any differences in knowledge among the three lecture density groups prior to the lecture can be attributed to chance. There was also no significant difference in the grade-point averages between the students who did or did not take posttest 2.

Table 2 summarizes the mean group scores on the pretest, posttest 1, and posttest 2. Significant effects were obtained for the lecture density grouping factor ($F[2,101]=6.47$; $p < .001$) and the time of test factor ($F[2,202]=239.49$; $p < .001$). A significant interaction effect between these factors was also obtained ($F[4,202]=2.90$; $p < .02$). This was primarily due to the small learning loss (2.26 points) exhibited by the medium density group between posttest 1 and posttest 2 as compared with the more substantial losses recorded by the low and high density groups (6.49 and 8.83 points, respectively). All three groups performed significantly better on posttest 1 than they did on the pretest ($p < 0.001$). However, posthoc statistical comparisons among the groups on this test indicated that the students attending the low density lecture scored significantly higher on posttest 1 than did the medium or high density groups. Although each group demonstrated a substantial degree of information retention two weeks later on posttest 2, statistical comparisons among the groups revealed that the low density group performed significantly better on posttest 2 than did the high density group. The smaller difference between the low and medium density groups on posttest 2 was not significant.

Tables 3 and 4 indicate the performance of the three groups on posttest 1 and posttest 2, respectively, on questions keyed to the time within the lecture when the pertinent information was presented. Within-group analysis indicated no significant difference in the low density group's retention of information presented during the first 15 minutes, middle 20 minutes, or final 15 minutes on post-

TABLE 2

Test Performance by Junior Medical Students Who Attended the High, Medium, and Low Density Versions of the Fibrositis Syndrome Lecture, University of Texas Medical School at San Antonio, 1983

Test	High Density		Medium Density		Low Density	
	No.	Percent*	No.	Percent*	No.	Percent*
Pretest	40	45.46	45	47.35	38	48.71
Posttest 1	38	79.42	44	77.57	38	88.67
Posttest 2	32	70.59	39	75.31	35	82.18

* The maximum score on all tests was 100 percent.

TABLE 3

Mean Percentile Posttest 1 Scores by 120 Junior Medical Students on Questions Keyed to the Time Within Fibrositis Syndrome Lecture When the Pertinent Information Was Presented, University of Texas Medical School at San Antonio, 1983

Timing of Information	High Density* (n = 38)	Medium Density* (n = 44)	Low Density* (n = 38)
First 15 minutes	N/A†	76.75	88.84
Middle 20 minutes	74.19	73.22	86.16
Last 15 minutes	84.66	82.75	91.01
Overall score	79.42	77.57	88.67

* The maximum score on all tests was 100 percent.

† No pertinent information relevant to test items was introduced in the first 15 minutes of the high density lecture.

TABLE 4

Mean Percentile Posttest 2 Scores by 106 Junior Medical Students on Questions Keyed to the Time Within Fibrositis Syndrome Lecture When the Pertinent Information Was Presented, University of Texas Medical School at San Antonio, 1983

Timing of Information	High Density* (n = 32)	Medium Density* (n = 39)	Low Density* (n = 35)
First 15 minutes	N/A†	73.04	82.36
Middle 20 minutes	65.90	74.60	79.53
Last 15 minutes	75.90	78.74	84.64
Overall score	70.59	75.31	82.18

* The maximum score on all tests was 100 percent.

† No pertinent information relevant to test items was introduced in the first 15 minutes of the high density lecture.

test 1 ($F[2,76] = 1.29; p = .282$) or posttest 2 ($F[2,68]=1.00; p = .373$). In contrast, the high density group performed significantly better on questions keyed to the final 15 minutes than on questions from the middle 20 minutes on posttest 1 ($F[1,37]=11.80; p < .01$) and posttest 2 ($F[1,31]=8.69; p < .01$). The medium density group performed comparably on all three phases of the lecture on posttest 2 ($F[2,78]=.19; p = .83$) but performed significantly better on questions from the final 15 minutes on the first posttest ($F[2,84]=3.81; p < .03$).

Comparisons of posttest 1 among groups indicated that the low density group scored significantly higher than the medium density group on questions from the first 15 minutes ($F[1,80]=11.05; p < .01$) and significantly higher than both other groups on the middle 20 minutes ($F[2,117]=6.55; p < .01$) but did not score significantly higher than the medium or high density groups on questions from the last 15 minutes ($F[2,117]=2.81; p > .05$). On posttest 2, the low density group scored significantly higher than the medium density group on questions keyed to the first 15 minutes ($F[1,73]=4.40; p < .05$) and significantly better than the high density group on questions pertaining to the midsection of the presentation ($F[1,65]=5.63; p < .05$). The small differences among the three groups for the final

15 minutes were not significant ($F[2,104] = 2.84$; $p > .05$).

Discussion

Interpretation of these data must be approached with caution. Since this study involved just one lecture topic and a single instructor, it is feasible that different results could be obtained from a study utilizing a different topic, a different population of students, or a different instructor. While there may be some risk in generalizations to other instructional settings, the results are probably applicable to most fields of graduate education where lectures constitute the major method of information transfer.

It is clear that students in this study learned and retained lecture information better when the density of new material was low. These results are consistent with Aiken's experiments on information density (10) and support the contentions of learning theorists who have advocated the low density approach (11). The implication is that the amount of information a student can learn within the span of a lecture is limited and the lecturer actually defeats his purpose by exceeding that limit. The data suggest that an instructor speaking at a rate of about four sentences per minute should introduce new material in only about 100 sentences during a 50-minute lecture. That would amount to approximately 50 percent of the total lecture time for an instructor speaking at an average rate. An equal period of time should then be devoted to reinforcement. It appears that medical students can learn effectively when the information density exceeds the 24 units per hour average reported by Anderson and Graham (2), but there still seems to be a density threshold beyond which retention declines. Although this threshold may be higher than previously estimated, most medical school lectures easily surpass the 33 units per hour used for the low density lecture in the present study.

A more difficult problem is to determine the mechanism responsible for decreased learning within the higher density groups. One could propose that the introductory information given to the high density group in some way altered retention of the key material. Interference is the most commonly invoked mechanism responsible for loss of memory that occurs after a presentation of new information (14). It appears that learning new associations (combinations of facts and theories) causes an individual to forget old associations and some new associations as well. Thus, past and present associations compete with each other in such a way that newly acquired knowledge impairs the individual's ability to retrieve previously learned material.

Three types of inhibition appear to modulate the degree of interference and consequently the rate of memory loss. They are: retroactive inhibition, proactive inhibition, and serial-position effect (14). Retroactive inhibition is interference by information learned at a later time. In the fibrositis syndrome lecture, for example, newly acquired information about treatment methods given late in the lecture could interfere with retention of data regarding clinical presentation given earlier in the lecture. In proactive inhibition, interference comes from information previously learned. For instance, the information about soft tissue rheumatism given early in the high and medium density lectures may have interfered with retention of information about fibrositis given later in the hour. According to the serial-position theory, the easiest portions of an informational sequence to learn are the beginning and end, while the most

difficult section is just beyond the middle (14).

All three lecture groups in the present study performed best on questions from information presented in the final 15 minutes of the lecture. This effect was most pronounced for the high density group, since these students performed significantly worse on questions pertaining to the middle 20 minutes on posttest 1 and 2. Since great care was taken to make the test questions in each phase of the lecture of equal difficulty, the results suggest that retroactive inhibition was the primary mechanism of interference for the high density group. After about 35 minutes of the high density lecture, the process of continually absorbing new information apparently caused students in this group to begin to forget what they learned earlier in the lecture. By contrast, the low density group demonstrated equal levels of retention during the beginning, middle, and end of the lecture.

This finding indicates that the teaching behaviors employed in the low density lecture minimized retroactive inhibition. Although the scores of students in the medium density group were consistently lower for all three phases of the lecture, this group exhibited a retention pattern similar to the low density group, particularly on posttest 2. Apparently, increasing information density by 20 percent for the medium density lecture was not enough to invoke the interference effect, whereas a 40 percent increase in density did so.

Previous investigators (15) have favored proactive inhibition as the explanation for memory loss. Thus, the results of the present study differ from the other studies. It should be noted, however, that most prior investigations of interference and forgetting have been conducted with elementary or secondary school children who were asked to memorize short passages of prose, number sequences, or nonsense syllables. In contrast, a medical school lecture requires attentiveness for a full 50 minutes rather than 3 to 4 minutes and involves mastery of a large volume of complex material. In support of this concept, Giles and colleagues (6) also found evidence for retroactive inhibition when studying medical students during a 50-minute lecture.

In the present study, students in the low density group may have been shielded from interference for several reasons. They had 40 percent less information to process mentally and thus had more time for reflection upon meaning and significance. As a result, the low density lecture group was probably less fatigued and thus more attentive during the lecture. The performances of the low and medium density groups on posttests 1 and 2 provide no suggestion of a serial-position effect upon retention. The effect of serial position could not be analyzed for the high density group, since there were no test items derived from the initial 15 minutes of that lecture.

Application of the current findings may require a substantial (30 to 40 percent) reduction of factual material in most medical school lectures. Such a change may be difficult for many instructors, but it appears that a switch from the high density (for example, "cover the field") strategy to the low density (for example, "amplify the basics") approach will have a positive influence on student retention of lecture material.

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