Examining the time course of memory retention for medical gross anatomy in first year medical students

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EXAMINING THE TIME COURSE OF MEMORY RETENTION FOR
MEDICAL GROSS ANATOMY IN FIRST YEAR MEDICAL STUDENTS

by

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EXAMINING THE TIME COURSE OF MEMORY RETENTION FOR MEDICAL GROSS ANATOMY IN FIRST YEAR MEDICAL STUDENTS

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ABSTRACT

During medical school students must learn and retain a large volume of information that is important for success in their future career as physicians. Laboratory studies have given insight into the mechanisms underpinning learning and memory, but few studies have examined the time course of memorial retention in a real world setting. The current study aimed to examine the memorial mechanisms used to retain information over time by using a variation of the Remember/Know/New recognition memory procedure to examine memory retention for anatomical information in first year medical students. Participants were presented with anatomical terms and asked to respond whether they Can Define the term, were Familiar with the term or Don’t Know the term. Participants’ Remember and Know responses are thought to be reflective of different processes, recollection and familiarity, respectively. We were particularly interested in examining differences in memorial retention based on retention interval (immediately at course end and after six months). All participants were enrolled in a Medical Gross Anatomy course. The course was divided into three successive modules, each of which culminated in an examination, module 1: Back and Limbs, module 2: Thorax, Abdomen and Pelvis, and module 3: Head and Neck. Participants completed a computer based memory task at three separate time points: prior to course start (session 1), after course
completion (session 2); and six months after course completion (session 3). Students were presented with anatomical terms from each module and asked to respond whether they Can Define, are Familiar with or Don’t Know a term. We predicted that responses would differ depending on when the module of the course was taught and when the testing occurred. Following work on primacy and recency, we predicted that at session 2 students would make the most Can Define responses to information learned most recently. We predicted that the second most Can Define responses would be to information learned the longest period of time from the testing session, and that information learned in the middle would be least well recalled (lowest number of Can Define responses). Furthermore, we predicted that familiarity responses would show the reverse pattern to Can Define responses at session 2. We also predicted that performance would differ by Session. We hypothesized that the proportion of Can Define responses would be higher for session 2 relative to session 3, due to the processes of forgetting. Furthermore, we predicted that recollective processes characterized by Can Define responses, would be most common in module 3, the module most recently studied relative to session 2. Lastly, we predicted that the number of Familiar responses would increase across the two sessions. Our results showed that responses varied based on when the information was taught in that participants made more Can Define responses to recently learned module 3 and earliest learned module 1 relative to module 2. Responses also varied by session, as the number of Familiar responses increased overall across session 2 and 3. At session 3, there were no significant differences in the proportion of Can Define or Familiar responses between the different modules of the course.
Theoretically, these results suggest that while the order of teaching impacts performance at course end, in the longer-term order of teaching ceases to matter and level of forgetting plateaus across modules. Practically however, a teacher’s aim is to maximize retention. Students might benefit from interleaving of course content instead of separate blocks, so that no one module is taught in the middle and more frequent testing to boost overall retention.
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INTRODUCTION

The first year of medical school provides the essential building blocks for development of clinical knowledge. Students must acquire a large volume of information, from Human Gross Anatomy and Physiology to Neuroscience, and then must integrate and retain it throughout medical school and beyond. Medical Gross Anatomy, or the form of the human body and the forms and locations of its many structures, arguably provides a basis for all future medical knowledge that students must acquire, if they are to be effective physicians. However, recent studies have indicated that medical students do appear to lose a substantial amount of basic science knowledge, including Anatomy. For example, D’Eon tested second year medical students on the loss of basic science concepts. The loss varied between courses, with students losing between 52.7% and 17.6% of prior knowledge, depending on the subject (D’Eon, 2006). Similarly, Lazic, Dujmovic, & Hren (2006) showed that basic science knowledge declined significantly between the second and final year of medical school.

Explorations of the memorial mechanisms that underpin memory retention have provided a foundation on which numerous studies have explored methods to improve overall retention. Thus far, great advances have been made in our understanding of the mechanisms that underpin learning and memory. Learning and memory are thought to occur in stages. When an event is experienced, incoming information is initially encoded. Following initial encoding, processes of consolidation begin, resulting in a robust
memory trace that can be easily accessed for later retrieval (Nadel, Hupbach, Gomez, & Newman-Smith, 2012).

Neurobiological processes occur at each stage of memory processing. During the process of memory encoding, the cortical patterns initiated by elements of the episodic experience (e.g. different sights, sounds, and emotions) are transferred to the parahippocampal cortex. Information is then transferred to the hippocampus, then entorhinal cortex and finally to the dentate gyrus and CA3 region respectively. At the CA3 region, the hippocampal index is assigned, storing episodic ‘cues’ so that a memory can later be retrieved. These “binding” processes in the medial temporal lobes creates a distinct memory episode that is initially stored within the hippocampus (Squire, Kosslyn, Zola-Morgan, Haist, & Musen, 1992);(Budson, 2009). Following encoding, consolidation processes make the memory episode less hippocampal dependent (Van Kestern, Ruiter, Morris & Fernandez, 2014). During these consolidation processes, memory traces that originally were stored in the hippocampus are transferred to neocortical regions such as the Medial Prefrontal Cortex (mPFC) where the memory becomes assimilated into a pattern of cortical connections (Frankland & Bontempi, 2006). This allows for retrieval of information from memory without dependence on hippocampal and medial temporal lobe structures (Budson, 2009).

In addition to memorial processes, memorial types have also been elucidated. The memory system can be further subdivided into declarative (consciously accessible) memories, and non-declarative (unconscious) memory, and declarative memory into episodic and semantic memory (Budson, 2009). Semantic memory is defined as memory
for facts such as London is the capital of England (Squire & Zola, 1998). Episodic memory is defined as memory for personally experienced events, such as one’s birthday. The components of episodic memory have been further elucidated by dual process models of episodic memory (e.g. Yonelinas, 2002). Dual process models suggest that two distinct processes, recollection and familiarity, underpin episodic memory (Rugg & Curran, 2007). Recollection is defined as a slow effortful process to consciously recall the learning episode and its associated contextual details (Rugg & Curran, 2007). Familiarity, on the other hand, is a fast, automatic process, when a feeling of having experienced the event before is accompanied by an inability to recall contextual details (Rugg & Curran, 2007). Recollection and familiarity processes are dissociated on a neural level. Studies of event related potentials (ERPs) related to these processes have found that distinct neural processes underpin recollection and familiarity. The early component at 300-500ms, the FN400, is thought to correlate with familiarity and the Late Positive Complex (LPC) at 500-800ms with recollective processes (Curran, 2000). In the context of the current study, these results shed light on the different processes that underpin memorial retention. We are interested in examining how these processes change overtime at a behavioral level.

In terms of medical education, one of the most relevant goals is to facilitate the retention of medical information students learn in their courses. Many investigations have examined what methods and techniques best improve memory retention (Roediger & Karpicke, 2006, Karpicke & Roediger, 2007, Mitchell et al., 2011). Two such methods that have proven successful in improving memory retention include the testing effect and
spaced learning. The testing effect, or the act of repeatedly retrieving information from memory during testing (Roediger & Butler, 2011), has been shown to improve overall memory retention compared to reading alone. For example, in a laboratory study, Roediger & Karpicke (2006) examined the testing effect using a two phase experiment. In the first phase, there were four seven-minute sessions in which participants either read a passage for the first time, restudied one of the passages, or took a test on one of the passages. The second phase of the study occurred after a time delay of five minutes, two days, or one week after the first phase study session. During the second phase participants were asked to recall the passages they had studied in the first phase. The results indicated that taking a test after studying material resulted in better performance after a delay of two days or one week, as compared to simply restudying the material in phase 1.

Several theories have tried to explain the testing effect. Early theorists suggested that the testing effect was the result of greater exposure to the material to be learned, resulting in overlearning (Slamecka & Katsaiti, 1988). However, repeated testing has been found to result in superior performance, even when study and test time are equated (Carrier & Pashler, 1992). More recently, theorists have suggested that repeated retrieval increases the strength of the memory trace, making retrieval easier (McDaniel & Fisher, 1991). The testing effect has also been observed in classroom environments. Logan, Thompson, & Marshak (2011) examined the testing effect in a cohort of future medical and dental students during a pre-entry program. In this study students took six 50-question quizzes that tested gross natomy concepts. For the quizzes an expanded set of questions on the nervous system were created to examine the effects of repeated testing.
This expanded set included three versions of the same question. Participants took two quizzes during the session approximately 30 minutes apart. A third and final quiz occurred after a one-week interval, following the second quiz session. Repeated testing was found to result in a 29% increase in scores between the first quiz and final quiz and scores on the quizzes were positively correlated with final exam grades. Logan et al. (2011) concluded that repeated testing was beneficial in the context of medical education and the study demonstrated successful application of the testing effect to classroom settings.

Spaced practice has also been found to be beneficial to retention in medical education. Spaced practice involves repeatedly retrieving information from memory after specific time intervals (Sobel, Cepeda, & Kapler, 2011). Kerfoot, DeWolf, Masser, Church, & Federman (2007) examined spaced education in fourth year medical students. The medical students completed a one-week urology rotation during a fourth year clerkship. Prior to the start of and after the completion of the urology rotation students completed a multiple-choice examination on four urology topics. After the completion of the rotation, students were sent weekly emails with relevant clinical questions or scenarios accompanied by multiple-choice questions. Students were randomly assigned to receive emails on two of the four urology topics. The emails were sent for either 6-8 or 9-11 months, depending on the date of the clerkship. The final outcome measure was the score of a 28-item test that the students completed at the end of the year. Participants’ results indicated that improvements in overall test scores were topic specific in that the students did better on the topics on which they had been repeatedly tested. Additionally,
the longer the students received the test emails, the greater their overall scores. The authors concluded that spaced practice could significantly increase retention of medical knowledge.

However, even with the use of these techniques to improve content retention, some decay in memory is inevitable (Roediger III, 1985). D’Eon (2006) tested second year medical students on loss of basic science concepts. Second year medical students were recruited to retake questions from the previous years Immunology, Physiology and Neuroanatomy courses. Students’ scores from their previous final examinations in these subjects were compared to their re-test scores. Results indicated that knowledge loss had occurred between the two tests. The loss of knowledge was varied, with students losing between 17.6-52.7% of prior basic science knowledge between the two tests. A similar study illustrated that a large proportion of Neuroanatomy knowledge was lost between the first and fourth years in medical school. When administered a test of neuroanatomical knowledge in their first year, medical students recalled on average 82% of neuroanatomy content. In their fourth year, medical students only recalled 33% on the same test of neuroanatomical knowledge; students had lost approximately 60% of prior knowledge (Mateen & D’Eon, 2008). In contrast, some studies suggest that medical professionals are able to retain a remarkable amount of basic science knowledge. Custers (2010) reviewed laboratory, classroom, and naturalistic studies examining long-term retention of basic science knowledge. The review indicated that, medical students are able to retain between two thirds and three quarters of the information one year after course completion. This
raises the question of what differences might exist between information that is or is not well recalled.

In the classroom, subjective memorial experience has been shown to be a predictor of test performance. Conway, Gardiner, Perfect, Anderson, & Cohen (1997) investigated changes in memorial awareness in Psychology undergraduates, specifically examining aspects of familiarity and recollection. First year Psychology students took multiple-choice examinations following the conclusions of each of seven psychology courses and again after 25 weeks. Conway and colleagues used a form of the remember-know paradigm to examine changes in memorial awareness. Following each question on the examinations students were asked to indicate if they ‘remembered’ the answer they just gave; ‘know’ the answer; were ‘Familiar’ with the information in the question; or simply ‘guessed’ the answer. ‘Remember’ responses represented explicit recollection of contextual details; ‘Familiar’ responses represented some sense of familiarity with the knowledge they previously learned, and ‘Know’ responses were reserved for information students could recall in the absence of contextual details. ‘Know’ responses were thought to reflect more general semantic memory (Conway et al., 1997). Conway et al. found that memorial awareness was predictive of examination performance. On examinations immediately following course conclusion, high performing students ‘remembered’ more than lower performing students. Following a 25-week delay, higher performing students ‘knew’ more psychology concepts than lower performing students. Conway et al. (1997) proposed a ‘schema plus episodic view’ of knowledge acquisition to explain these results. This view suggests that during the initial learning episodes learners rely on episodic
memory, linking new knowledge they gain to the specific learning episode and subjective memorial experience will be dominated by recollection as opposed to familiarity. Over time the knowledge becomes integrated into semantic schemas, and the subjective experience will shift to feelings of ‘just knowing’. Some items however, will be dominated by ‘familiarity’, feelings of having previously encountered an item, but inability to recall the associated contextual details (Conway et al., 1997).

The richness of episodic memories has been shown to be important for learning. Herbert & Burt (2004) had students study information that was either rich in detail and examples or information that lacked detail. Participants took two examinations consisting of multiple choice and short answer questions, the first after two days and second after five weeks. In the multiple-choice examination, students were assessed using a remember-know task similar to that used by Conway et al. (1997). Students who studied ‘episodically rich’ information made more ‘remember’ responses (they had stronger episodic memories) than those who studied the less detailed information (Herbert & Burt, 2004).

Medical Gross Anatomy presents an opportunity to examine rich episodic memory. Students take part in dissection laboratories and work to locate and clean structures such as muscles and organs and their vasculature and innervations. Initially, experience of these dissections is likely to create strong episodic memories with many contextual details. Over time, the individual concepts such as ‘common fibular nerve’ are likely to become less strongly associated with a specific episode and incorporated into a semantic schema, e.g. that of the ‘lower extremity’.
Even with strong episodic memory, as noted earlier, some knowledge loss is inevitable and not all memories will form sufficiently strong traces to be recalled and some will lose contextual details and dwindle to familiarity traces only. Medical school teaching often occurs in sequential blocks of time. For example, students may learn anatomy of the Back and Limbs first. This is followed by anatomy from the Thorax, Abdomen, and Pelvis, followed finally by the anatomy of the Head and Neck. Following each block, an examination is given, often with no cumulative final examination. This provides an interesting scenario for study of the changes in memorial mechanisms over time.

Early studies indicated that order of presentation has a profound effect on later recall. Primacy and recency have been thoroughly examined in the memory literature. The primacy effect refers to better memory for items studied first, while the recency effect to better memory for items studied last (Roediger, 1985). In comparison, items studied in between are not remembered as well (Roediger, 1985). Primacy and recency effects have been shown to influence recollection, but not familiarity. Jones & Roediger (1995) examined the basis of serial position effects in relation to the dual process memory model. Participants studied eight lists of words and took free recall tests on four of the lists. They then took a recognition test on all the items and were asked to classify the words as ‘old’ or ‘new’ (i.e., not on the previous lists). For those words classified as ‘old’ they were asked to judge if they recalled the actual occurrence of the word in the list (‘remember’ response) or were familiar with the word (‘know’ response). Their results indicated that prior recall enhanced recognition, as indicated by an increased number of
‘remember’ responses. Secondly, primacy effects were only shown in items classified as ‘remember’ and not in items classified as ‘know.’ Recency effects were also present for the four tested lists. Overall, Jones and Roediger suggested that serial position effects are reflected in ‘remember’ responses and ‘know’ responses are not particularly influenced by serial position.

It is clear that order of presentation has an effect on memorial processes. Memorial processes have also been shown to change over time. Tsivilis et al. (2015), found differences in ERP correlates for remote and recent recognition memory. The study took place over two sessions. In the first session, participants studied pictures and were required to rate them as pleasant or unpleasant. In the second session, which followed an average of twenty-eight days after the first, participants studied a second set of pictures. Following the second study session, participants took a recognition memory test of remote, recent, and new items. ERP recordings indicated that remote recognition memories were characterized by presence of the FN400, but absence of the late parietal component (LPC). The authors suggested that the absence of the LPC is a result of loss of episodic detail over time (Tsivilis et al., 2015). The exact time course was not examined, but the authors predicted that it might be characterized by rapid initial loss following encoding, followed by gradual decline (Tsivilis et al., 2015).

Based on prior evidence that the order of learning and distance from the learning episode can influence the components of episodic memory, the aim of the current study was to examine the time course of memory retention in first year medical students studying Medical Gross Anatomy, a course rich in episodic detail. In the current study,
students were tested on their knowledge of anatomical terms in three sessions: prior to the
start of the course, at the conclusion of the course and six months following the
conclusion of the course. During each session, participants were presented with
anatomical terms from each module of the Gross Anatomy course (Back and Limbs,
Thorax, Abdomen and Pelvis, Head and Neck), which had been taught in consecutive
order (see figure 1), and obscure anatomical terms. For each term the students were asked
to make memorial awareness judgments, Can Define if they could define the term,
Familiar if they had seen the term before, but could not define it and Don’t Know if they
did not know the term at all.

<table>
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<th>Module Number</th>
<th>Teaching Sequence</th>
<th>Duration of module</th>
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</thead>
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<tr>
<td>Back &amp; Limbs</td>
<td>Module 1</td>
<td>First</td>
<td>5 weeks</td>
</tr>
<tr>
<td>Thorax-Abdomen-Pelvis</td>
<td>Module 2</td>
<td>Second</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Head &amp; Neck</td>
<td>Module 3</td>
<td>Third</td>
<td>3 weeks</td>
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*Figure 1 Course Breakdown*

Our predictions follow the theoretical explanations outlined by Conway et al.
(1997) and Tsivilis et al. (2015). We were particularly interested in examining differences
in states of memorial awareness between the different modules of the course,
immediately at course end and six-months after the end of the course. In the context of
Primacy (superior recall of distantly learned information) and Recency (superior recall of
most recently learned information), we predicted that performance would differ by
module of the course, module 3 the most recently completed module of the course, would
be remembered best at course end (as characterized by a higher proportion of Can Define responses), because the strength of episodic memories would be greatest at that time, followed by module 1, as this module has the benefits of primacy effects. Module 2, because it occurs in the middle of the course does not have the benefit of primacy and recency, therefore will be least well remembered, as reflected by remember responses.

Furthermore, even though familiarity tends to be a common feature of all memory and from this we would predict that primacy and recency would have little impact on familiarity responses (Jones & Roediger, 1995), the set up of our study (the fact that sum total of the proportions of all responses (Can Define, Familiar, Don’t Know) made for each module would be equal to 1 because participants were required to select one of the memorial judgments and if they could not define a term it would likely be familiar to them or they would not know it) meant that familiar responses were likely to be inversely proportional to Can Define responses at session 2.

We also predicted that performance would differ by session. We hypothesize that proportion of Can Define responses would be higher for session 2, relative to session 3, due to the processes of forgetting.

Finally, we were interested in differences in the types of responses across the different modules and sessions. We predicted that recollective processes, as characterized by proportion of Can Define responses, would be most greatly utilized in module 3, and in session 2. In terms of Familiarity, we predicted that it would increase across the two sessions, as characterized by increase in familiar responses.
METHODS

Participants: 59 right-handed adults (24 males, $M_{\text{age}}=23.1 \text{ yrs}$, $SD=2.02$) were recruited for this study, 2 were first year graduate students at Boston University School of Medicine, the remainder were first year medical students. All students were proficient in English and had either normal or corrected vision. All participants were enrolled in the sixteen-week Medical Gross Anatomy in either Fall 2013 or Fall 2014, and none had previously taken a formal Gross Anatomy course. The students were recruited via two emails sent one month and one week prior to the start of the first baseline session. These emails outlined the study and participation criteria. All participants gave written consent to participate; participants were reimbursed for their participation. Participation in the study had no impact on course grades.

Design and stimuli: The protocol for this study was approved by the Boston University Institutional Review Board. There were three phases to the experiment and each participant was tested individually during each phase. Session 1 occurred during the two weeks before the start of the Gross Anatomy course. The second session (session 2) occurred within the weeks following the conclusion of the Gross Anatomy course. The third and final session (session 3) occurred six months after course completion. Each session was two to three hours in duration. During the course each module of the course was taught sequentially (see figure 2) in the following order: Back and Limbs (module 1); Thorax, Abdomen and Pelvis (module 2); and Head and Neck (module 3). Stimuli consisted of 264 anatomical terms, all of which were presented in each of the three sessions. Half of the terms ($n=132$) were relevant terms taken from the learning
objectives of the Gross Anatomy course (e.g. gastrocnemius, omentum, buccinators). These anatomical terms were divided equally to reflect the content of the three modules of the Gross Anatomy course (44 terms per module). In addition, there were 44 obscure anatomical terms from an outdated anatomy textbook (Fonahn, 1922), which should have been unfamiliar to the students (e.g. Alagmur). The same 132 relevant terms were used for each experimental session but the 44 obscure terms were changed for each session to avoid overlap between the sessions.

Procedure: Each of the three experimental sessions had the same format. The 176 terms were presented to the participants on a 12-inch Dell computer monitor using E-Prime 2.0 (Schneider, Eschman, Zuccolotto, 2002). Participants were instructed that they would see a succession of anatomical terms, presented one at a time, and would be asked to make a decision for each. At the conclusion of the experiment they would complete a post-test on a subset of the terms or definitions. During each experimental session, participants were asked to decide if they Can Define the term (they would be able to define the structure, function or location of the term if asked), they were Familiar with
the term (they recognize the term, but would not be able to define its structure, function or location if asked) or they Don’t Know (Do not know) the term. All decisions were self-paced. Participants input their decisions on a keyboard. Participants pressed 1 for Can Define, 2 for Familiar and 3 for Don’t Know. In each trial there was a 1500 millisecond (ms) inter-stimulus interval (ISI) following the participant response and prior to the presentation of the next term.

The post-test occurred following the conclusion of the experiment. The purpose of the post-test was to ensure that the Can Define responses were representative of the participants’ true ability to recollect the terms. The post-test was created individually for each participant after each session. The post-test terms were a randomly selected subset of the anatomical terms that the participant had said they could define during the experimental phase. Participants were presented with the either the definitions of the anatomical terms or the terms, as derived from Stedmen’s medical dictionary (Stedmens, 2011) or Merriam-Webster’s medical dictionary (Merriam-Webster, 2006), and were asked to generate either the appropriate term for each definition or the appropriate definitions for the terms. A criterion of 50% correct on the post-test was set for inclusion in the analysis. A participant who scored less than 50% or who did not complete to post-test was excluded from the analysis. As a result, 6 participants were excluded for failure to reach the post-test criteria. Another 8 participants were excluded as a result of dropout and one other was excluded due to incorrect completion of the experimental procedure. Data from 44 participants was included in the analysis.
Data Analysis

The proportion of each response type (Can Define, Familiar and Don’t Know) was computed by dividing total number of response type by total number of relevant terms, in each module (44 terms for each module). These proportions were calculated for each module of the course and for experimental sessions 2 (course end) and 3 (6 month follow-up). Response data was analyzed using 3 (Response Type: Can Define, Familiar, Don’t Know) X 3 (module: 1, 2, 3) X 2 (Session: 2, 3) repeated measures Analysis of Variance (ANOVA).

RESULTS

A criterion of 50% correct on the post-test in session 2 and 3 was set for inclusion in the analysis. Eight participants were excluded as a result of drop-out, a further 6 were excluded for failure to reach the post-test criteria, and 1 was excluded due to incorrect completion of the experimental procedure. Data from 44 participants was included in the analysis.

A main effect of Response Type was observed ($F(2,86)=135.587, p<0.001$, partial $\eta^2 = .951$). Post-hoc t-tests using Bonferoni corrected alpha level ($\alpha = .016667$) were used as described below. Participants made significantly more Can Define responses, than Familiar ($t(43)= 6.392, p < .001$) or Don’t Know response ($t(43)= 16.977, p < .001$), and significantly more Familiar than Don’t Know responses ($t(43)= 13.962, p < .001$). No main effect of either Session ($F$s = 1, $ps <.1$) or Module, ($F$s = 1, $ps <.1$) was observed (see figure 3 for overall proportions by module and sessions).
The effects of temporal order on memorial awareness

We predicted that the order in which the course content was taught would impact memorial awareness. Specifically, we predicted that at session 2, participants would be best able to recall information most recently taught to them, followed by the information taught earliest and information taught in the middle of the course would be least well recalled, as characterized by the proportion of Can Define responses. Our prediction was supported. A significant Module X Response Type interaction was observed, \( (F(2,86)=49.284, p<0.001, \text{partial } \eta^2 = .534) \). During session 2, participants made significantly
more Can Define responses for module 1 terms, \((t(43)= 7.222, p<.001)\) and module 3 terms, \((t(43)= -15.583, p<.001)\) compared to module 2 terms. In addition, participants were able to make more Can Define responses to module 3 terms, relative to module 1 terms, \((t(43)= -8.647, p<.001)\) (see figure 4).

![Figure 4 Proportion of Can Define responses across modules at session 2](image)

In terms of Familiar responses our results were consistent with our prediction that Familiar responses would show the inverse pattern to Can Define responses, at session 2 participants made significantly more Familiar responses to module 2 terms compared to module 1 terms, \((t(43)= -5.432, p<.001)\) and module 3 terms, \((t(43)=17.196, p<.001)\), in addition, participants made more Familiar responses to module 1 terms, relative to module 3 terms, \((t(43)= 9.122, p<.001)\). (See figure 5).
For Don’t Know response, at session 2, participants made significantly more Don’t Know Responses for module 2 terms relative to module 1 terms, \((t(43)=-4.779, p<.001)\) and module 3 terms, \((t(43)=4.006, p<0.001)\). However, no significant differences were observed for Don’t Know responses, between module 1 and module 3, \((t(43)=1.525, p=.135)\) (See figure 6).

Figure 5 Proportion of Familiar responses across modules at session 2
The effects of delay on memorial awareness

We also predicted that performance would differ by Session. We hypothesize that the proportion of Can Define responses would be higher for session 2 relative to session 3, due to the processes of forgetting during the six-month delay. Although we did not observe a main effect of Session, a significant Session X Response Type interaction was observed ($F(2,86)= 39.471, p<0.001, \text{ partial } \eta^2 = .479$). To further explore this interaction, pair-wise t-tests were conducted to analyze differences of Response Type across sessions. T-test analysis revealed significant differences in Response Type across sessions. We observed a significant decline from session 2 to session 3, in the proportion
of Can Define responses for module 1 ($t(43)=4.828, p < .001$) and module 3, ($t(43)=9.701, p < .001$), but not module 2, ($t(43)=1.297, p=.202$) (See figure 7).

Familiar responses showed the reverse pattern (see figure 8). There was a significant increase in Familiar responses from session 2 to session 3, in module 1, ($t(43)=-5.137, p<.001$) and module 3, ($t(43)=-10.047, p<.001$), but not module 2 ($t(43)=-.742, p=.462$). For Don’t Know responses, we observed no significant changes in the proportion of this response type from session 2 to session 3, in any of the three modules (see figure 9).

Figure 7 Decline in Can Define responses between session 2 and 3
Figure 8 Increase in Familiar response between session 2 and 3
A significant Module X Session X Response Type interaction was also observed, 
\( F(4,172) = 59.146 \ p < .001, \ \text{partial } \eta^2 = .579 \). To further elucidate this interaction, a set of 
2 X 3 (Session X Module) repeated measures ANOVAs were conducted for each 
response type (Can Define, Familiar and Don’t Know).

For Can Define responses we observed a main effect of Session wherein 
participants made more Can Define responses overall in session 2 compared to session 3, 
\( F(1,43) = 40.147 \ p < .001, \ \text{partial } \eta^2 = .485 \). A main effect of module was observed, 
participants made the most Can Define responses to module 3 terms and the least in 
module 2 terms, \( F(2,86) = 73.169 \ p < .001, \ \text{partial } \eta^2 = .630 \). Furthermore, in session 2, 
significant differences were observed in the proportion of Can Define responses between 
the different modules of the course. In support of our hypothesis that at session 2,
participants would be best able to recall information most recently taught to them, followed by the information taught earliest and information taught in the middle of the course would be least well recalled, analysis showed that participants were able to define significantly more module 3 terms relative to module 1 ($t(43)=-8.647, p<.001$) and module 2 terms ($t(43)=15.583, p<.001$). In addition, participants were able to define significantly more module 1 terms relative to module 2 ($t(43)=7.222, p<.001$). In addition, a significant Session by Module interaction was found, ($F(2,86)= 74.740 p<.001$, partial $\eta^2 = .635$). Pairwise comparisons revealed a significant decline in Can Define responses between session 2 and 3, in module 1 ($t(43)= 4.828, p<.001$) and module 3 ($t(43)= 9.701, p<.001$), but not module 2 ($t(43)= 1.279, p = .202$). However, in session 3, no significant differences were observed in the number of Can Define responses between the different modules of the course.

For Familiar responses, we observed a main effect of Session, ($F(1,43)= 43.411 p<.001$, partial $\eta^2 = .502$), participants made more Familiar Responses overall in session 3, relative to session 2, Supporting our prediction that Familiar responses would increase between session 2 and 3. There was also a main effect of module on Familiar responses, ($F(2,86)= 39.066 p<.001$, partial $\eta^2 = .476$), the results of which are described below. Follow up pairwise comparisons revealed significant differences in the proportion of familiar responses between the different modules of the course. Overall, participants made marginally more Familiar responses to module 2 terms, relative to module 1 ($t(87)=-2.860, p = .005$) and significantly more Familiar response to module 2 terms
compared to module 3 terms ($t(87)=6.364, p<.001$) and significantly more Familiar responses to module 1 terms relative to module 3 terms ($t(87)=5.509, p<.001$).

We also observed a significant Session by Module interaction, ($F(2,86)= 65.944 p<0.001$, partial $\eta^2 = .605$). Pairwise comparisons were conducted to elucidate this interaction. Analysis revealed a significant increase in Familiar responses between session 2 and 3, in module 1 ($t(43)=-5.137, p<.001$) and module 3 ($t(43)=-10.047, p<.001$), but not module 2 ($t(43)=-.742, p=.462$). In support of our prediction that Familiar response would show the inverse pattern of Can Define responses at session 2, analysis also revealed significant differences in Familiar responses in session 2, between the different modules of the course. Participants made significantly more Familiar responses to module 2 terms relative to module 1 terms ($t (43)=-5.432, p<.001$) and module 3 terms ($t(43)=17.196, p<.001$), Furthermore, when Familiar responses in module 1 and module 2 in session 2 were compared, participants made significantly more Familiar responses to module 1 terms, ($t(43)=-9.122, p<.001$). However, no significant differences in Familiar responses were observed between the different modules of the course in session 3.

For Don’t Know responses we observed a main effect of Session ($F(1,43)= 7.309 p=.010$, partial $\eta^2 = .145$) in which participants made more Don’t Know responses in session 3. There was also a main effect of module, ($F(2,86)= 18.359 p<0.001$, partial $\eta^2 = .299$) in which participants made more Don’t Know responses to module 2 terms overall relative to module 1($t(43)=-4.986, p<.001$) and module 3 terms ($t(43)=4.430, p<.001$). However, there were no differences in Don’t Know responses between module 1 and
Lastly, we did not observe a Session by Module interaction, \( (F(2,86)= 1.682 \) \( p=. 192, \) partial \( \eta^2 = .038 \).)

**DISCUSSION**

The current study sought to examine the time course of memory retention for gross anatomy in first year medical students, in order to provide insight into how learned knowledge changes over time, and to determine what memorial mechanisms are used at different time points. We used a variation of the remember/know recognition memory procedure to examine differences in subjective memorial awareness between the different modules of a Gross Anatomy course (Back and Limbs (module 1), Thorax, Abdomen and Pelvis (module 2), Head and Neck (Module 3), immediately following the conclusion of the course and after a six-month interval. We had a number of predictions. First, we predicted the proportion of Can Define responses in each module of the course at session 2 would differ, depending on when the module was originally taught. Because in the context of primacy and recency, earlier and later taught information is better recalled than information in the middle (Roediger, 1985). Module 1 was taught first, followed by module 2 and module 3 was taught last. Specifically, we predicted an order effect such that information taught first and last would be best recalled. In terms of Familiar responses at session 2, we predicted that they would show the inverse pattern to Can Define responses due to the set up of our experiment. We also predicted that performance would differ by session. Can Define responses reflect the strongest memories with the most episodic detail, and we expected the strongest memories to be present immediately following course completion. Specifically, we hypothesized that the proportion of Can
Define responses would be higher immediately following the course during session 2, relative to those six months later during session 3. We also predicted that the proportion of Familiar responses would increase for all modules of the course from session 2 to session 3.

In addition, we were interested in differences in the type of responses across the different modules and sessions. We predicted that memorial recollection as characterized by Can Define responses would be most common in module 3, the most recent module to be studied and in session 2, immediately following course end. In terms of Familiarity (characterized by Familiar responses), we predicted that it would increase across the two sessions.

**The effects of temporal order**

We were interested in examining how differences in the time between learning and testing correlate with differences in memorial awareness. Previous research has shown that, typically, items that occur in the middle of a learning session are least well remembered (Onifade, Jackson, Chang, Thorne, & Allen, 2011). In the Gross Anatomy course the students were taught the anatomy of the Back and Limbs (module 1), followed by Thorax, Abdomen and Pelvis (module 2), and Head and Neck (module 3) was the last module of the course to be taught. Therefore we predicted that content from the middle module of the course would be least well remembered. Consistent with our predictions, at session 2 the students best remembered the most recently studied module of the course (module 3), followed by the first module of the course (module 1) and remembered least well the module that occurred in the middle the course (module 2). These results are
consistent with some findings of Onifade et al. (2011) they examined serial position effects in a semester long accounting course. Onifade et al. (2011) had students learn nine chapters in 3 separate blocks. Each block of chapters was followed by an examination. Each block contained 3 chapters. The chapters were taught in sequence (i.e. 14,15,16) or reverse sequence (i.e. 16,15,14). Onifade et al. (2011) predicted that earlier and later learned information would be better recalled. They found some support for their hypothesis, primacy and recency effects were present; content from earlier and later chapters was better recalled than the middle chapters.

In addition, in line with our prediction; Familiar responses also differed by module of the course and showed the inverse pattern to Can Define responses. At session 2, participants made the most Familiar responses to module 2 terms, followed by module 1. Participants made the least amount of Familiar responses to module 3. This result suggests that participants had less episodic recollection for terms associated with module 2 because either recollection had declined at a faster rate in this module relative to the other two modules of the course, or they simply did not learn all the terms efficiently during the course for strong episodic memories.

The overall decline in Can Define responses from session 2 to session 3 also differed for the content of the three different modules of the course. Can Define responses declined significantly between session 2 and 3, for module 1 and module 3, but not module 2. Interestingly, there were no significant differences in the number of Can Define responses between the different modules of the course at session 3, because the relative declines in Can Define responses between sessions 2 and 3, were greater for
module 1 and module 3 content than for module 2 content, for which Can Define responses did not decline significantly. These results indicate that despite differences in the proportion of Can Defines in session 2 between the modules of the course, at session 3, the level of forgetting seemed to plateau across modules.

Familiar responses increased between sessions 2 and 3, for module 1 and module 3 terms but not for module 2 terms. These results are generally consistent with Conway et al.’s finding that over time, recollection (as indicated by Can Define responses) is more prevalent closest to the learning episode when more contextual details are present; over time as contextual details are lost, there is a shift toward familiarity.

Don’t Know responses also differed by module of the course. Participants made more Don’t Know responses to module 2 terms relative to module 1 and module 3 terms. However, what they did not know (as measured by proportion of Don’t Know responses) in this module did not seem to decline substantially between sessions 2 and 3, there were no differences in the number of Don’t Know responses between sessions 2 and 3.

Overall, these results are consistent with other studies examining longer-term retention of medical knowledge. Our results indicate that even when students learn material in blocks, resulting in primacy and recency effects, in the longer term, the order of teaching had little impact on later recall, and the level of forgetting seems to plateau across modules, perhaps a result of the information that remains being incorporated into semantic memory and resulting in students ‘just knowing’ the material, even in the absence of contextual details (Conway et al., 1997). The results of the current study are consistent with research examining long-term retention of medical knowledge; for
example, Custers & Ten Cate (2011) examined long-term retention of medical knowledge in doctors, many years after graduation. Custers and Ten Cate compared retention of basic science knowledge in medical students who were close to graduation (in their fifth and sixth years of medical school) to those of medical professionals who had graduated many years earlier. Participants completed a written examination on basic science concepts. Before providing an answer to each question, participants were asked to make judgments of their knowledge such as ‘I knew this, but I have forgotten this’. Their results indicated that even doctors that had graduated many years previously were able to score 75% of the score of current 5th and 6th year medical students. These results suggest that the practicing doctors were able to retain a substantial amount of basic science knowledge, even after many years (Custers & Ten Cate, 2011).

The overall decline in Can Define responses and increase in Familiar responses between session 2 and 3 is consistent with the finding by Tsivilis et al. (2015). They found that the presence of ERP correlates associated with recognition and familiarity, differ for remote and recent memories. Remote memories, further from the learning episode, are characterized by the presence of the ERP signal for familiarity, the FN400, but the absence of the LPC signal of recollective processes. Over time the richness of episodic memory declines, leading to an increase in the use of familiarity for more remote memories (Conway et al., 1997).

These results raise questions of what factors might have caused less information to be retained overall in module 2, and what can be done to prevent forgetting overall. Over the course of the six-month retention interval students seemed to lose recollective
details of the study episode and familiarity increased. Theoretically, it could be argued that this is not a significant problem, some research has shown that although recall of basic science knowledge declines, loss of basic science knowledge does not impact test performance on clinical questions (Lazic, Dujmovic & Hren, 2006). Practically, however, a teacher’s aim is to maximize retention. Students might still benefit from regular testing even after the completion of a module or course. Larzic et al. also showed that although retention of basic science knowledge does not directly impact clinical knowledge, retention of basic science concepts is positively correlated with clinical knowledge. Taking more regular tests or introduction of a cumulative final might still be beneficial and could help interrupt forgetting of the content of the middle module. Indeed, Szpunar, McDermott, & Roediger (2007) showed that the expectation of a cumulative final increases long-term retention of learned information.

**The effects of delay**

In addition, we were interested in examining the effects of a six-month retention interval on memorial awareness. As predicted the proportion of Can Define responses differed as a function of testing session (immediately at the end of the course vs. six months afterwards). Overall, participants made more Can Define responses in session 2 relative to session 3. In contrast, Familiar responses showed an overall increase between sessions 2 and 3. This result was unsurprising given that detailed episodic memory will be highest immediately at the end of the course, as learned information has had little time to decay from memory. Then over time, as episodic details of learned information decay, individuals shift to utilizing their sense of familiarity to recognize information they
learned previously or have incorporated the information into semantic memory and ‘just know’ the information (Conway et al., 1997). Participants also made a greater proportion of Don’t Know responses at session 3, relative to session 2, as would be expected when students forget material during the intervening 6 months. These results are consistent with previous research by Conway et al. (1997) and Herbert & Burt (2004) who indicated that more recent episodically rich memories are filled with contextual details from the learning episode, but over time the episodic richness declines, and reliance on familiarity increases.

From a practical perspective, our results have a number of implications. Our results suggest that over a short-term interval order of teaching can affect retention, and that after a longer retention interval the order of teaching ceases to matter and learners plateau at a certain level of forgetting across the three modules. A number of strategies may be useful to minimize this knowledge loss. To maintain retention of anatomical concepts in all modules of the course, a useful strategy might be interleaving of the course modules so that no one module is taught in the middle. Interleaving (intermingling concepts from related topics to be learned during a learning episode, instead of learning specific blocks of material (Kornell & Bjork, 2008)) has been shown to be effective in improving learning and memory retention. Kornell & Bjork, (2008) examined massed vs interleaved study of multiple artists’ paintings. The paintings of artists were either presented serially as a massed set or interleaved with the paintings of other artist. During the test phase, participants were presented with unfamiliar painting by the artists. They were asked to indicate by button press which artist they thought each was painted by.
Their results indicated that interleaved studying resulted in significantly better performance at test compared to massed studying. Similarly, interleaving of test questions has been shown to boost performance. Rohrer & Taylor (2007) had participants work on practice problems, either in blocks of the same problem type or in an interleaved fashion. After a weeklong retention interval, those who completed the practice problems in an interleaved manner scored 63% correct on new problems compared to just 20% for those who completed the problems in a blocked fashion. In conjunction with the current study, these results suggest that students might benefit from a presentation of material and practice testing in an interleaved fashion, instead of learning material in blocks. In addition, as previously mentioned, introduction of more regular tests or a final cumulative test might help boost overall retention.

The current study was conducted in an ecologically valid classroom environment. However there were some limitations to this study design. The naturalistic classroom setting meant that we were unable to manipulate the order of the modules of the course. This would have been beneficial to allow us to control relative difficulty of the information studied. However, we believe the fact that Can Define responses plateaued across modules at session 3 ameliorates this shortcoming. It indicates that no intrinsic differences between the modules of the course existed at session 2 and order of teaching is causing the observed differences. Furthermore, it was assumed due to the structure of the Gross Anatomy course and the medical school curriculum more generally that students did not review material during the retention interval. However, students may have come across terms during other classes or during clinical experiences.
In order to expand on the current results, future research might consider examining the time course of memory retention in more controlled laboratory settings, controlling for the level of difficulty and incorporating ERP recordings to examine the time course of memory retention at a neural level.

In conclusion, the current study sought to investigate the time course of memory retention for Medical Gross Anatomy in first year medical students, to provide increased insight into the changes in memorial mechanisms over time. We adapted the traditional remember/know paradigm to classroom settings, to examine how retention, measured via subjective memorial awareness, changes over time. The results of this study revealed that immediately at course end, recollection varied based on when the material was taught, with material well remembered for the most recently and most distantly taught material, and least well for the material taught in between, indicating an order effect. After a six-month retention interval, however, participants’ recollection of the material did not differ with respect to the different modules of the course, suggesting order of teaching has an impact on shorter-term retention but less so on longer-term retention and participants plateau at a certain level of forgetting across the three modules. Theoretically, these results suggest, that order of teaching affects performance at end of course, following a delay; order of teaching has little impact on the level of forgetting. Practically however, teachers aim to maximize retention and, we can infer that students might benefit from interleaved teaching of gross anatomy, instead of separate blocks, so that no one module is taught in the middle and more frequent testing to improve overall retention.
LIST OF JOURNAL ABBREVIATIONS

PNAS  Proceedings of the National Academy of Sciences of the United States of America
REFERENCES


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CURRICULUM VITAE

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EDUCATION

M.S. Anatomy and Neurobiology (Vesalius Program)
Boston University School of Medicine, MA, USA (2014-2016, expected)

B.Sc. Psychology
University of Exeter, UK (2011-2014)
Degree achieved: Upper Second Class Honors (2.1)
Final Year Research Project: The effects of delayed feedback following errorful
generation, supervised by Dr. Fraser Milton, University of Exeter.

University of Cambridge International Summer School (August 2012)
Courses taken: Children, Teachers and Education: Contemporary Issues, Historical
Perspectives, Historical Perspectives: Threats and Challenges in Contemporary Britain,
Sciences in the Ancient World.

A-levels
Shiplake College (2008-2010)
Oxford Tutorial College (2010-2011)
Biology (A) Psychology (A) Government & Politics (A) History (B) AS ICT (B)

GCSEs
Cranford House School (2006-2008)
Science (A) Additional Science (A) History (A*) Food Technology (A) Information
Communication Technology (A) Religious Studies (short course)(A) English(C) English
Literature (B) Maths(C)

AWARDS
CIFE College Prize, Oxford Tutorial College (2011)
• Awarded to the highest achieving final year students at each of the CIFE
associated Colleges, presented at the House of Lords, London, UK.

Oxfordshire Biologist of the Year, Shiplake College (2010)
- Awarded to the highest achieving A-Level Biology students in Oxfordshire at the University of Oxford Museum of Natural History, UK.

Santander Urban Impact Microgrant recipient (2016)
- Won a grant of $1950 for youth engagement program, Educan! The program aims to help fifth graders in Boston’s South End foster a growth mindset that they can practice and implement in their daily lives. During the 7-week pilot program, 1 hour per week, mentees work individually with mentors, through activities to help them challenge and change their mindset.

COMMITTEES
Raviola Memorial Day Committee
Boston University School of Medicine (September 2014– present)
- Work as part of a team of three to host this annual seminar and reception.
- Responsible for organizing the reception event, including coordinating the advertising, catering, decorations and set up.

EDUCAN!
Boston University (January 2016- present)
- Coordinator and a founding member of EDUCAN!
- The aim of this organization is to work with local middle schools in the Boston area to help children at risk of underachieving develop or maintain a ‘Growth Mindset’ and develop their study skills by teaching the students neurological principles of effective studying.

RESEARCH AND TEACHING EXPERIENCE
Centre for Translational Cognitive Neuroscience, Boston, MA, USA (May 2015- present)
- Assist in setting up EEG for participant testing, analysing EEG recordings and carried out statistical analysis on the both EEG and behavioural data, using statistics package SPSS.
- I have carried out literature searches, which have helped to hone my research and analysis skills.

Teaching Assistant and Prosector, Gross Anatomy, Section 1: Back and Limbs, Boston University School of Medicine (September – October 2015)
- Worked with a team of 4th year medical students to dissect cadavers prior to each first year gross anatomy lab session; assisted the first years students with dissections in and outside of class and set up and ran a mini osteology practice practical for them, prior to the examination.

University of Exeter final year research project: The effects of delayed feedback following errorful generation (October 2013-May 2014)
• Designed a psychological research study from first principles with another final year student, with guidance from advisor Dr Fraser Milton.
• Undertook study design, participant recruitment, testing, and data analysis using SPSS statistical package.

WORK EXPERIENCE
University of Exeter Open Day Representative (July 2013)
• Worked as part of the open day team in order to provide a high level of guidance and assistance to prospective students as they toured the campus.

Macfarlanes LLP, London, UK (June 2012)
• Observed legal procedures and reviewed documents.

Davies Group, Accounts Department, Reading, UK (July 2012)
• Used my skills of analysis to check spreadsheets for errors, added descriptions to data in spreadsheets and carried out data searches to assist accountants.

Stirring Stuff Cookery School (2010-2012)
Database and spreadsheet creation
• Created a simple and user-friendly stock spreadsheet to record incoming and outgoing stock.
• Carried out training demonstrations for staff regarding the operations of the software.

Kitchen Assistant
• Assisted with kitchen hygiene and food preparation.

Goring Veterinary Surgery (UK) (July 2009)
Sonning Common Veterinary Surgery (UK) (July 2008)
Penrith Veterinary Surgery (UK) (August 2008)
• Assisted the team of veterinary nurses in their duties.
• Observed veterinary surgeons carry out procedures.

VOLUNTEERING
ISCA College Mindset Mentor, Exeter, UK (January – April 2014)
• Mentored children at risk of underachieving at school using Carol Dweck’s ‘Mindset’ principles. Helped students to focus on the importance of effort as opposed to achievement. This position helped my develop my skills as a listener and respond to the needs of each child.

University of Exeter Biological Psychology Mentor (January – April 2014)
• Mentored first year psychology students who were experiencing difficulty with the more challenging aspects of the first year biological psychology course. Worked with both individuals and groups.
Stokenchurch Dog Rescue (UK), (August 2010)
  • Operated as part of a team to feed, clean and walk dogs.

OTHER

Skills
Experience with Google SketchUp
  • Self-taught to help me prototyping my own designs.

SPSS statistical package
  • Experience with data entry and running various statistical tests, including analysis of variance, correlation and regression analysis.

Women’s Coding Collective online courses
  • HTML Basics course (September 2015)
  • CSS Basics course (October 2015)

Travel
  • Singapore, Australia and New Zealand (July and August 2013)