



Spacing Learning Over Time

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The “spacing effect” is one of the most reliable findings in the learning research, but it is, unfortunately, one of the least utilized learning methods in the workplace learning field.

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“The spacing effect is one of the oldest and best documented phenomena in the history of learning and memory research.”

Harry Bahrick & Lynda Hall (2005, page 566), quoted in the Journal of
Memory and Language, a well-respected refereed journal.

Summary

This report reviews research on the spacing effect and related learning factors from the preeminent refereed journals on learning, memory, and instruction.

The research shows that spacing learning over time produces substantial learning benefits. These benefits result from different mechanisms, including those based on repetitions and those based on other factors. Spaced-repetition effects are particularly noteworthy given the enormous research literature supporting their use.

The following findings are highlighted in the report:

1. Repetitions – if well designed – are very effective in supporting learning.
2. Spaced repetitions are generally more effective than non-spaced repetitions.
3. Both presentations of learning material and retrieval practice opportunities produce benefits when utilized as spaced repetitions.
4. Spacing is particularly beneficial if long-term retention is the goal – as is true of most training situations. Spacing helps minimize forgetting.
5. Wider spacings are generally more effective than narrower spacings, although there may be a point where spacings that are too wide are counterproductive. A good heuristic is to aim for having the length of the spacing interval be equal to the retention interval.
6. Spacing repetitions over time can hurt retrieval during learning events while it generates better remembering in the future (after the learning events).
7. Gradually expanding the length of spacings can create benefits, but these benefits generally do not outperform consistent spacing intervals.
8. One way to utilize spacing is to change the definition of a learning event to include the connotation that learning takes place over time – real learning doesn't usually occur in one-time events.

How This Research Report Is Organized

To create the best experience for you – the reader – this report begins by conveying the research findings in straightforward language, and only toward the end of the report does it jump into the vernacular of the research community.

After the initial review of the findings, examples and case studies are provided to ensure that you can visualize how the research is applicable to real instructional-design situations. Questions are provided to strengthen your learning and help clarify key points. The research is then summarized in depth. Finally, the 100-plus research articles cited in this report are listed.

The sections can be outlined as follows:

- The Findings Concisely Conveyed
- Applications and Examples
- Case Studies of Real-World Applications
- Questions to Reinforce Learning
- Extensive Research Support
- List of Supporting Research Studies

What is the Spacing Effect?

When we talk about the spacing effect, we are talking about spacing repetitions of learning points over time. The spacing effect occurs when we present learners with a concept to learn, wait some amount of time, and then present the same concept again.

Spacing can involve a few repetitions or many repetitions. Spaced repetitions need not be verbatim repetitions. Repetitions of learning points can include the following:

1. Verbatim repetitions.
2. Paraphrased repetitions (changing the wording slightly).
3. Stories, examples, demonstrations, illustrations, metaphors, and other ways of providing context and example.
4. Testing, practice, exercises, simulations, case studies, role plays, and other forms of retrieval practice.
5. Discussions, debate, argumentation, dialogue, collaboration, and other forms of collective learning.

Repetitions can also be delivered to different perceptual modalities (visual, auditory, olfactory, kinesthetic) and through different learning media (text, audio, video, computer, internet, classroom, etc.).

Regardless of the way repetitions are manifested, if two or more presentations of the same learning point are repeated with some sort of time delay between them, they are likely to produce the spacing effect.

So what is the spacing effect? It is the finding that spaced repetitions produce more learning – better long-term retention – than repetitions that are not spaced. It is also the finding that longer spacings tend to produce more long-term retention than shorter spacings (up to a point where even longer spacings are sometimes counterproductive).

Note that distributing unrelated, non-repetitious learning events over time does not officially constitute the spacing effect. When we give learners a rest between learning sessions, we may limit their learning fatigue, but we're not necessarily providing them with all the advantages that spacing can provide. Again, the spacing effect occurs when repetitions of learning points are distributed over time.

What Causes the Spacing Effect?

Despite the fact that the spacing effect is one of the most studied phenomena in the field of learning research¹ its causes are still being debated and discussed. The following reasonable explanations have been put forth:

1. Wider spacings require extra cognitive effort and such effort creates stronger memory traces and better remembering.
2. Wider spacings create memory traces that are more varied than narrow spacings, creating multiple retrieval routes that aid remembering.
3. Wider spacings produce more forgetting during learning, prompting learners to use different and more effective encoding strategies that aid remembering in the future.

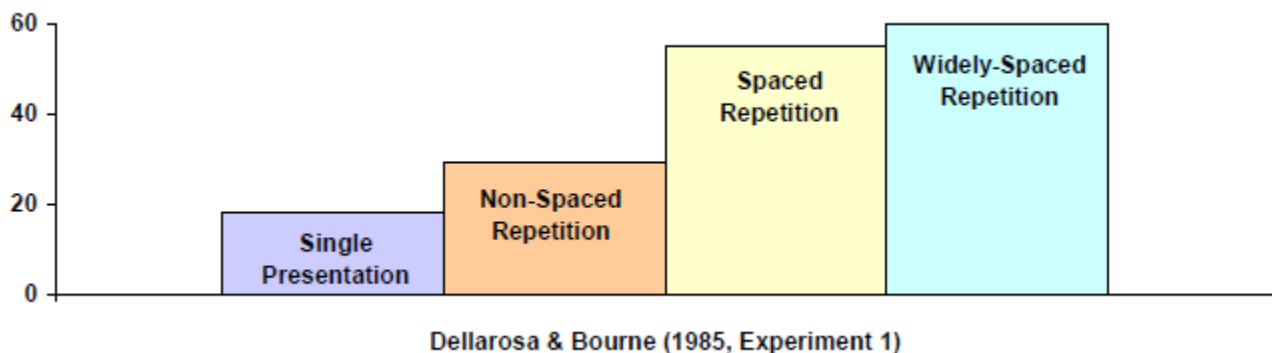
¹ One of the reasons the spacing effect is so often researched is that the phenomenon runs counter to our everyday understanding of how learning works. How can it be that exactly equal learning presentations – the first one using a widely spaced repetition and the second one using a narrowly spaced repetition – produce different levels of learning? The spacing effect is also researched extensively because it sheds light on the fundamental nature of human thinking and cognition.

What Benefits Accrue When We Space Learning Over Time?

We've already hinted at the most important benefit. Spacing improves learning results. But it's extremely important to be specific about this.

Spacing repetitions over time facilitates long-term remembering. It enables our learners to store information in memory in a manner that makes the information more resistant to forgetting than non-spaced repetitions. This needs to be put into perspective from two different vantage points.

First, repetitions are good, but spaced repetitions are better. The following graph shows that repetitions are better than single presentations of learning material, spaced repetitions are better than non-spaced repetitions, and widely-spaced repetitions are better than narrowly-spaced repetitions. Of course, the results in the graph below represent only one research study and your results will vary depending upon the learners, the learning materials, and many other factors as well. Still, the general principles are likely to apply.



Second, spaced repetitions are not always better than non-spaced repetitions in creating short-term memory retrieval. In other words, if your learners need to remember something for only a short time – for example 15 minutes – wider spacings are much less likely to provide advantages over narrowly-spaced repetitions (as compared to situations that require long-term retention). We are all familiar with the antithesis of the spacing effect – the cramming effect. If we bunch our learning into a short time frame, we can do well when we have to retrieve information soon after learning, but we tend to quickly forget what we learned. How much do you remember from your freshman biology class?

To summarize, spacing helps learners remember over relatively long time frames. It is less helpful – or not helpful at all – for short-term remembering.

The benefits of spacing can also be considered from another perspective. Spacing repetitions over time reduces the number of repetitions that are needed to produce the same level of learning results. For example, in one experiment we'll describe later, the number of repetitions needed was reduced by half – simply by increasing the spacing interval between repetitions.

Other Benefits of Spacing

Although not discussed in the spacing-effect research literature, it is likely that spaced repetitions provide additional benefits in addition to long-term memory retrieval. For example, other research paradigms have shown that spaced repetitions can be beneficial in making ideas more persuasive and products more desirable. These effects aren't always straightforward (for example, more repetitions don't always lead to more persuasion or more desirability), but they do show some potential to influence the success of our learning interventions.

Training often involves some form of persuasion. Essentially, we want learners to change their behavior on the job. Sometimes this involves changing long-term habits, long-held beliefs, or lifelong values. One-time training immersions just won't cut it when we need to ask so much of our learners.

Desirability can play a part in learning as well. People tend to spend more time thinking about things they care about. They tend to avoid ideas and things they dislike. The more our learning concepts seem enjoyable (to think about or work with), the more time learners will attend to them. The more attention given, the more those concepts will be enriched and reinforced. Trainers and training facilitators may be subject to similar effects. The more times a learner encounters a trainer, the more that learner may come to respect and admire that person (assuming of course that the trainer is worthy of admiration, as most are). Such feelings may lead learners to engage at a deeper level with the learning materials.

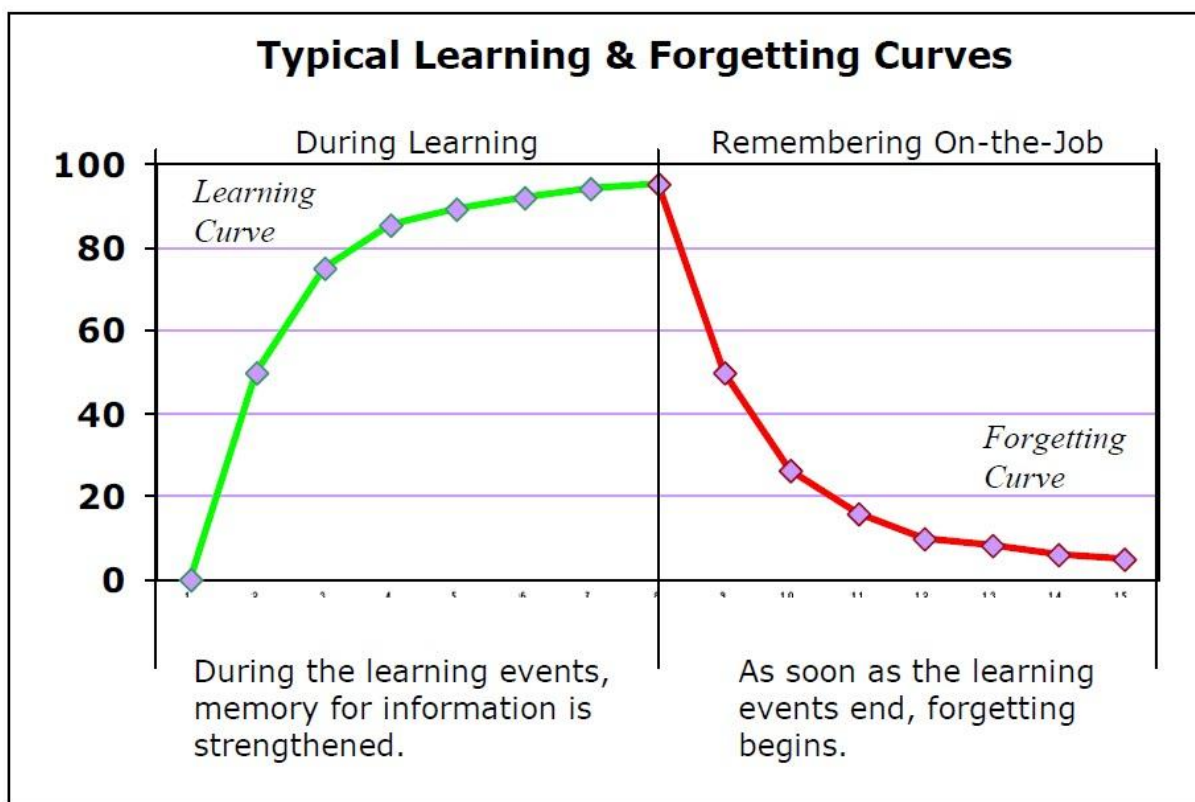
Finally, spaced repetitions may bring learning events closer to the time when they will be needed on the job. The more time that passes between learning and application, the more our learners experience forgetting. As soon as learning events end, forgetting begins. By adding subsequent spaced repetitions, we essentially extend learning and lessen forgetting.

Side Effects of Spacing

Spacing repetitions over time has some side effects. Spaced repetitions typically cause a temporary increase in forgetting between the times when the beneficial repetitions are delivered. Learners are prompted to forget early to remember later. This forgetting, though generally shown to spur learning activity, might be frustrating for some learners. From a purely logistical perspective, spacing may be difficult to implement. Sometimes we can't get our learners to sit down to learning material after long delays. Finally, spacing's biggest hurdle may be its challenge to training-industry orthodoxy – we as instructional professionals, haven't used it in the past, so we don't think to use it now.

Spacing Benefits Mapped to the Learning & Forgetting Curves

It may be helpful to think about the spacing effect from the standpoint of both learning and forgetting. People learn and people forget. Our role as instructional designers is not just to maximize learning, but also to minimize forgetting. The learning and forgetting curves portrayed in the diagram below capture some of the essential properties of human cognition.²

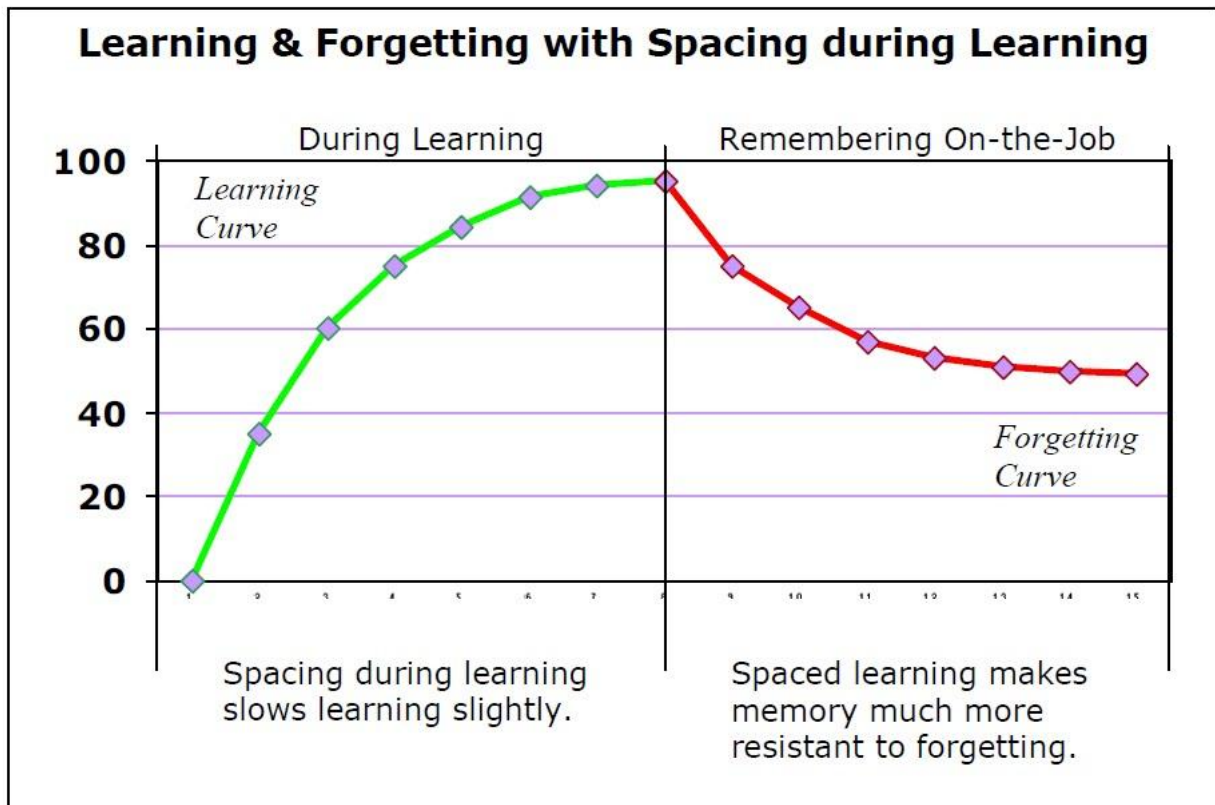


Notice that people tend to learn things relatively quickly, but that true expertise takes time and lots of learning effort. Note also that forgetting happens rather quickly in most situations.

Why am I covering all this? Because it is vital to understanding the primary benefit of the spacing effect – that it facilitates long-term remembering. In other words, it reduces the slope of the forgetting curve.

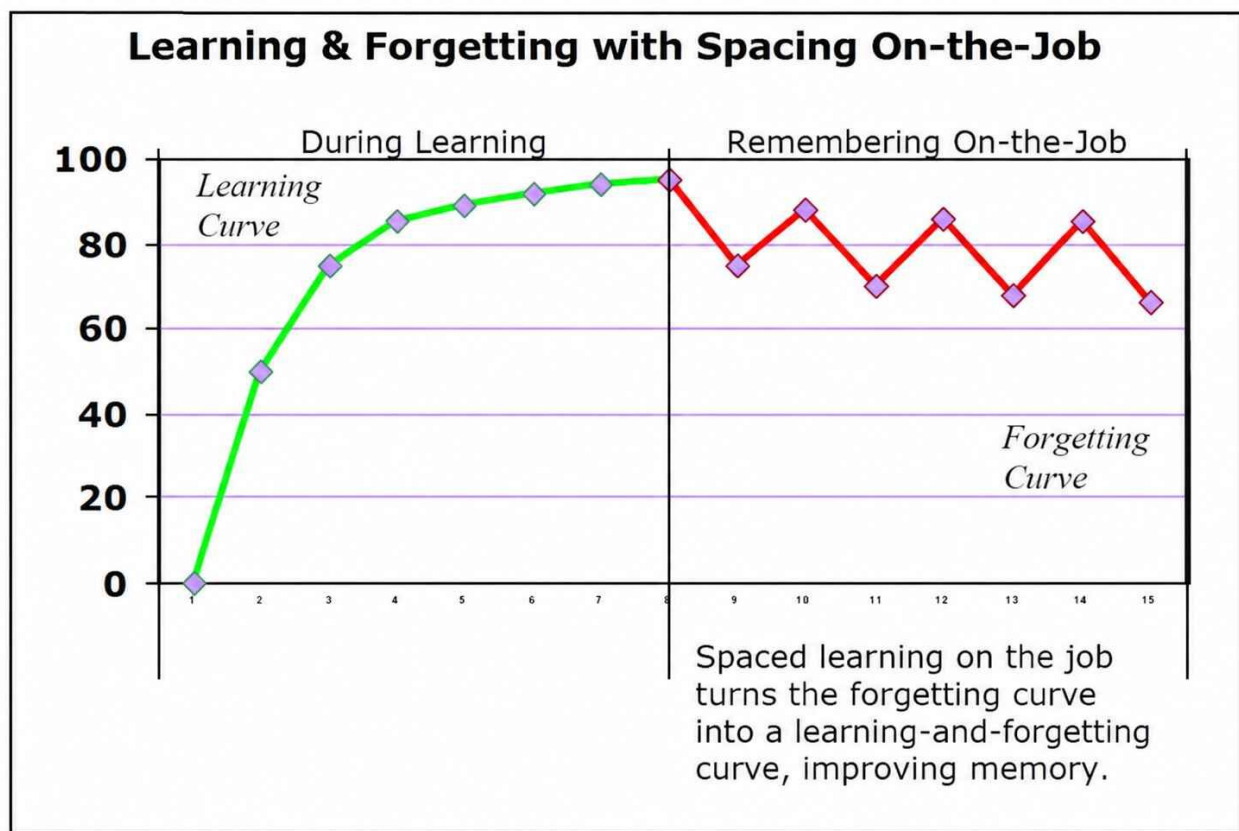
² Because all learning situations are unique, the curves displayed are only representative of the general concepts involved. Your learning results will vary.

The diagram below depicts the addition of spaced repetitions to the primary learning events. You'll note that the learning curve is less steep than the typical one, indicating the learning is often more difficult with spaced repetitions. More importantly, you'll also see that the forgetting curve is much less severe. To summarize the gist of the diagram, spaced repetitions help minimize forgetting, while creating minor and temporary difficulties during learning.



Compare this diagram to the one on the previous page. You'll notice how spaced repetitions have slowed learning slightly but significantly reduced the amount of forgetting that occurred.

The final diagram shows what happens when spaced learning events are added during the on-the-job experience of the learners. Again, the primary learning events are depicted on the left and the on-the-job experience is depicted on the right. When we provide spaced repetitions on the job, the forgetting curve becomes a learning-and-forgetting curve. The additional learning can help maintain high levels of remembering.



One of the implications of the learning/forgetting curve discussion is that we ought to consider pushing learning closer to the time when it will be needed on the job. The closer in time learning is delivered to the situations when it is needed, the less forgetting will be a factor. The less forgetting, the more learners will be able to remember what they learned and apply it to their jobs.

For example, suppose that, in January, we teach learners how to properly handle ten dangerous safety-related situations, but they don't actually experience one of those on-the-job situations until July. Forgetting and failure will be much more likely than if we also provided our learners with monthly spaced repetitions from February through June. Of course, we do need to realize that just-in-time learning is not usually feasible for complex learning topics. It will take someone more than a few minutes to learn a language, become a skilled mechanic, or understand the American political system.

Benefits of Learning Mechanisms Tangential to Spacing

As we discussed above, the spacing effect involves repetition of learning concepts. What about spacing unrelated learning sessions over time – without repeating any of the learning material or learning points? Will this produce any advantage? It may. One thing we all know from our own experience as learners is that learning can be hard work. Long learning sessions can create fatigue, inattention, and cognitive processing that is less intense and effective than the ideal. To prevent such learning fatigue, learners may benefit from having unrelated learning sessions spaced over time.

On the other hand, it's important to be clear that the “spacing effect” implies some sort of repetition of the learning message. So, though it may be helpful to space unrelated learning sessions to avoid fatigue, the spacing effect goes beyond fatigue prevention.

Distributing learning sessions over time – whether these sessions repeat learning points or not – may induce extra studying as well. This is especially true if learners feel that the new material will require prerequisite knowledge. Learners who have been away from material may be inspired to refresh their knowledge before they go on to the next topic. They know from experience that if they don't understand what came before, the new material just won't make any sense.

This “re-learning” effect can apply equally to spacing or non-spacing situations (that is, those involving spaced repetitions and those involving new material).

Finally, spacing learning sessions over time – because it enables different mental contexts to be utilized – may push learners toward more creative perspectives on the material being learned. For example, say you are learning about instructional design in a course that spans the months from February through June. In each week of that five-month period, you will have different things on your mind – you will be working on different instructional design projects, different content, different design issues.

So, if the learning material in the course is repeated periodically throughout the five months, you will have many opportunities to weave the spaced threads of knowledge into a variety of cognitive structures – relating the spaced material to many different concepts and situations. Such variety will not only help you remember the spaced concepts better (the spacing effect), but it will also enable you to more creatively apply the spaced knowledge to your real world of work³.

³ Creativity is not just a question of individual predispositions. Creativity can be increased when people have recent experience with varieties of relevant information.

How Can We Create the Spacing Effect?

Conceptually, there are two ways to create the spacing effect. We can put a delay between two or more repetitions or we can present other learning material between two or more repetitions. The table below shows the different ways we can space repetitions of “Topic A” over time.

	Insert a Delay Between Repetitions	Insert Other Topics Between Repetitions
1.	Topic A	Topic A
2.	<i>wait</i>	<i>Topic B</i>
3.	Topic A	Topic A
4.	<i>wait</i>	<i>Topic C</i>
5.	Topic A	Topic A

To reiterate, between the repeated presentations of Topic A we can either wait or we can provide learning opportunities on other topics or learning points.

Adding Spacing to Intact Learning Events

Spacing can be designed into our learning interventions or it can be added to augment our existing programs. Suppose you previously designed a one-day workshop delivered by an instructor in a classroom. Learning could be spaced by adding additional repetitions of key learning points either before or after the workshop. This could be done in a variety of ways, for example, by having the learners read an article before coming to the workshop or having them practice in a simulation after the training. Conceptually, we can think of this as adding spacing before and after our primary learning events.



We can augment many different types of “primary learning events” in this way. We can facilitate long-term retention by adding repetitions to e-learning, computer-based training, classroom training, videos, books, podcasts, mentoring, on-the-job learning, tutoring, and even informal-learning.

Unique Opportunity for E-learning

E-learning has a unique advantage over classroom training programs and stand-alone computer-based training applications. It offers us – as creators and managers of learning – the opportunity to connect with our learners in a meaningful way over time. For many learners, after the training the manual goes on the shelf and the concepts learned are never considered again, much less utilized on the job. E-learning is no panacea, but it does offer us a unique opportunity to stay connected to our learners. We, of course, must figure out how to provide our learners with interesting, useful, and engaging spaced learning events.

Prompting Others to Support Learning

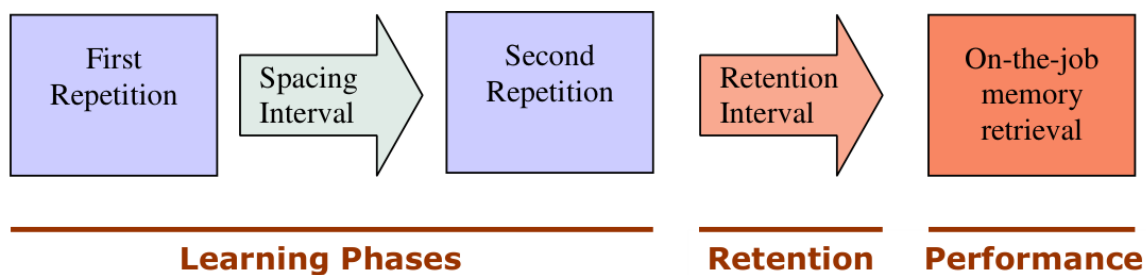
On a similar tangent, e-learning methodologies can be utilized to help others support and reinforce learners’ efforts at learning. For example, learners’ managers can be prompted (1) to give their direct reports time and permission for learning, (2) to demonstrate or describe how newly-learned concepts are applicable to the workplace, (3) to encourage learners to apply what they’ve learned in their current work efforts, and (4) to acknowledge and reward good learning efforts.

How Many Spaced Repetitions are Enough?

One critical point to consider is that spacing may not produce an effect unless more than one or two or three repetitions are used. This is especially critical when difficult, lengthy, or technical learning materials are used. Let's face it. When there is a lot to learn, or when the learning material is complex, learners will need more repetitions. When learning events are spaced out, the difficulty of learning complex or lengthy materials may be compounded, and so, the advantages of spacing may only become evident when enough repetitions are used to enable a basic threshold of learning.

What is the Right Spacing Interval?

It appears from the research that the ideal spacing interval should be roughly equal to the retention interval – the time between the last learning opportunity and the time when the information is needed on the job. So for example, if you know your learners will have to remember information for two weeks before needing to apply that information on the job, then the ideal time between repetitions should be two weeks. In the diagram below, the arrows represent the intervals we should try to equalize.



Again, if the retention interval is one week, the spacing interval should be one week. If the retention interval is eight months, the spacing interval, ideally, should be eight months. But note how I used the word, “ideally”. While the ideal spacing interval may maximize long-term remembering, we don’t have to be tied to the ideal to get learning benefits. In fact, most instructional-design situations don’t lend themselves to having really long spacing intervals.

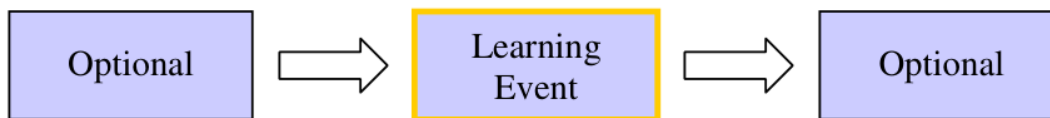
What can be done? First, we should remember that longer spacing intervals tend to be better than shorter ones. We can also space repetitions from one day to the next. There appears to be a great advantage to one-day delays. If this is not feasible, we can use 4-hour spacings instead of 2-hour spacings, 1-hour spacings instead of 15-minute spacings, and 10-minute spacings instead of an immediate repetition.

Reframing “The Learning Event”

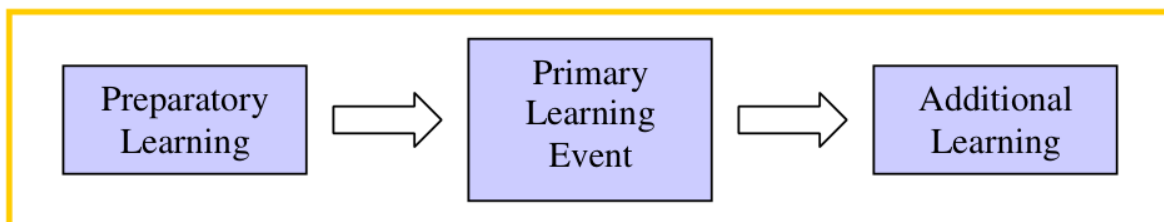
To add spaced learning, it is often necessary to prompt our learners to stretch their concept of what constitutes “the learning event.” For example, many learners see a classroom workshop as a learning event, but view additional learning as extra and optional. It’s the same thing with e-learning. When someone completes a 45-minute program, they think they’re done. These expectations have been built up through long experience with typical learning sessions, but they are not immutable. As instructional designers, we should probably accept some of the blame for these expectations. More importantly, we can set different expectations in our new designs.

As the research shows, we do our learners a disservice if we push them toward single-event learning interventions. It’s not that these interventions are bad, they’re just not nearly as effective as they might be.

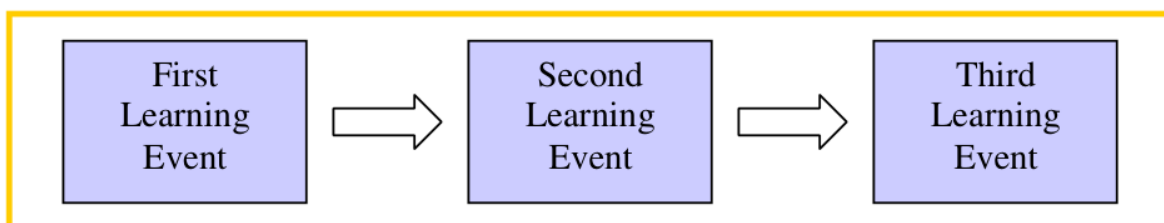
Old Way



New Way #1



New Way #2



Learning Events are framed in gold. As illustrated, the newer framings can prompt learners to more fully utilize spaced learning.

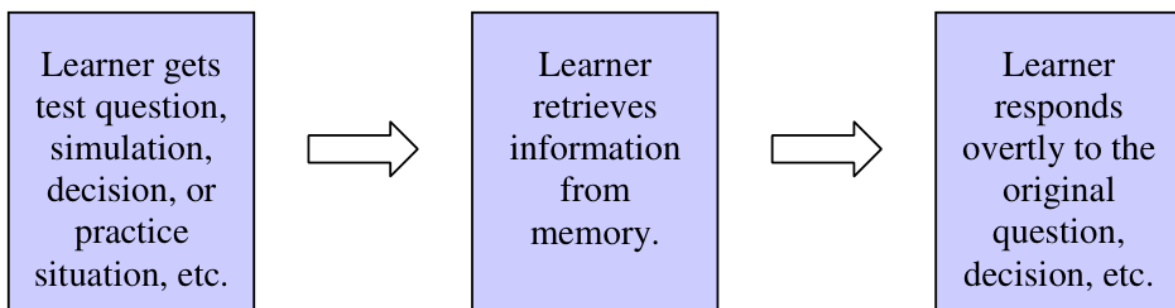
Presentation versus Retrieval Practice

Although the spacing effect applies to repetitions in general, it is helpful to differentiate between two types of repetitions, (1) presentation, and (2) retrieval-practice opportunities. Examples of each are presented in the table below.

Presentation	Retrieval Practice
<i>Explanations</i> <i>Descriptions</i> <i>Examples</i> <i>Illustrations</i>	<i>Tests and Quizzes</i> <i>Simulations</i> <i>Decision Scenarios</i> <i>Skill Practice</i>

As you can see, the major difference between the two is that retrieval practice requires the learner to respond to some learning material by retrieving information from memory and making an overt response. Retrieval practice can be diagrammed as follows.

Retrieval Practice



Why is this distinction important in relation to the spacing effect? Because retrieval-practice opportunities sometimes benefit by gradually increasing the time between repetitions, while expanding the time between presentations doesn't elicit this benefit. It's also important because we ought to realize that we're not limited to using the spacing effect only for straightforward presentations of information.

Using Gradually Expanding Spacing Intervals

Suppose we presented management trainees with leadership scenarios on a periodic basis to help them maintain their learning. Suppose further that each scenario covers a particular learning point. The table below shows us how we might gradually increase the spacing of scenarios covering Learning Point A. As before, I'm making a distinction between spacing by delay or by inserting other learning material between repetitions.

Expanding Spaced Repetitions		
	Using a Delay Between Repetitions	Inserting Other Topics Between Repetitions
1.	Scenario on Point A	Scenario on Point A
2.	<i>wait 1 day</i>	<i>Scenario on Point B</i>
3.	Scenario on Point A	Scenario on Point A
4.	<i>wait 2 days</i>	<i>Scenario on Point B</i>
5.	Scenario on Point A	<i>Scenario on Point C</i>
6.	<i>wait 6 days</i>	Scenario on Point A
7.	Scenario on Point A	<i>Scenario on Point B</i>
8.	<i>wait 20 days</i>	<i>Scenario on Point D</i>
9.	Scenario on Point A	<i>Scenario on Point E</i>
10.	<i>wait 60 days</i>	<i>Scenario on Point F</i>
11.	Scenario on Point A	Scenario on Point A

As you can imagine, this process can prove a bit cumbersome, especially if you have a lot of learning points to cover. Still, it may be worth utilizing expanding spaced repetitions in some situations. See the next page for details.

The research on expanded spacings is still a bit cloudy. Both types of spacings – consistent and expanding – are better than no spacings at all. In other words, it is clear that the spacing effect works for both. What is a bit unclear is determining when one type of spacing is better. The table below offers some tentative recommendations.

Which Type of Spacing is Better, Consistent or Expanding Spacings?			
	Presentation	Retrieval Practice with Feedback and Relearning	Retrieval Practice with No Feedback and No Relearning
<i>What it Does</i>	<i>Prompts learners to perceive the information</i>	<i>Prompts learners to respond to cues, and then provides corrective feedback</i>	<i>Prompts learners to respond to cues, but provides no corrective feedback</i>
<i>Which is Better?</i>	Equal. <i>Consistent and expanded spacings are beneficial to an equal extent</i>	Equal. <i>Consistent and expanded spacings are beneficial to an equal extent</i>	Expanding maybe. <i>Expanded spacings sometimes produce better results</i>

As the chart above suggests, there aren't that many real-world learning situations in which expanded spacings are better than consistent spacings. For presentations, consistent and expanded spacings are equally beneficial. For retrieval practice, expanded spacings only produce added benefits when we don't give our learners feedback on their retrievals – and in real-world instructional designs we only occasionally forgo feedback.

The reason that expanded spacings may provide an advantage when learners don't get feedback – and don't get a chance to relearn the information – is that the initial narrow spacings help the learners maintain the retrievability of the information. This is critical because (without corrective feedback) once the learners forget the information; they have no way of recovering it.

Expanding spacings are usually more difficult to accomplish than consistent spacings. On the other hand, expanded spacings may be useful to keep learners interested over long practice sequences. To summarize, in most cases we can use both types of spacings, but expanding spacings may have some benefit when we provide no feedback or relearning.

Utilizing Forgetting to Spur More and Better Learning Behavior

A relatively new strand of research suggests that spaced retrieval practice can generate learning by first prompting retrieval failure. When learners fail to retrieve information from memory, that failure can serve as a warning. Subsequent opportunities to learn information related to the previous failure generate more vigorous and constructive learning behaviors.

Most retrieval failures occur when learners can't recall information – not when learners recall the wrong information. Both types of failure seem to motivate learners to utilize more energetic and better encoding strategies when they get a subsequent chance to learn the same information. In other words, retrieval failures generate better learning behavior when additional opportunities are presented. Note that it's not better learning in general, but better learning related to the specific information they failed to retrieve.

How does this relate to spacing? First, spaced retrieval practice is more likely to generate retrieval failures than non-spaced retrieval practice. Second, the longer – more authentic – the time delay, the more the test of retrieval will force learners to adopt productive cognitive encoding strategies. Third, spacing is inherently about repetitions and subsequent repetitions are needed to enable learners to employ extra attentional processing.

Does this mean that failure is always something to encourage? Absolutely not! It's often more efficient to have learners learn the information and then help them maintain that level of memory accessibility. But since forgetting is a natural process, when learners do forget, we want that forgetting to promote the kind of cognitive processing that will engender long-term retrievability. Spaced retrieval practice does that. And what's really convenient is that spaced retrieval practice is also the best way to maintain memory accessibility over time. So, to be absolutely clear about this, spaced retrieval practice is one of the best things we can do to maintain memory accessibility and spur productive learning behavior when memory accessibility fails.

It might be helpful to think of spaced retrieval practice as the aspirin of instructional design. Like a miracle drug, it has multiple benefits and very few negative side effects.

Examples of Spaced Learning

Instructional professionals utilize spaced repetitions in many ways already, and more and more innovations are being developed as the spacing effect becomes better understood. The following is a short list of spaced-learning examples.

1. Midi, a compliance solution provider, utilizes four-minute multimedia e-learning segments that prompt learners to make realistic compliance decisions. These are delivered to learners once a month to reinforce previously-learned concepts or to introduce new topics before a subsequent learning program.
2. Type A Learning Agency, creators of the “e-learning campaign,” draws on learning and advertising research to create e-learning delivered over time. They use e-learning to generate later on-the-job conversations that reinforce learning.
3. Zenger-Folkman, a leadership development and e-learning company, developed ActionPlan Mapper to support learners on the job in implementing what they learned and to get the learners’ managers involved in support and review.
4. Sharon McGann, Director of A Passion for Results, an Australian performance-improvement company, has found that simple email reminders after training programs help her learners remember to apply what they’ve learned.
5. Allen Interactions, founded by industry guru Michael Allen, gives learners practice making decisions and provides expanding spaced retrieval-practice opportunities depending on how well the learner is doing. When information is not retrieved, extra practice is given.
6. Knowlagent, a call-center services company, provides call-center reps with 15- minute e-learning segments, periodically delivered to the reps when call volume is down, enabling the reps to experience repetitions of key learning points over time.
7. ADP, developers of accounting software and services, provides its software customers with e-learning that is spread over several days and delivered in two or three sessions. Their online courses utilize a spaced design with many iterations, including presentations explaining the overall design of the software, examples of how to perform tasks, and practice on specific procedures.
8. Trainers who ask learners to discuss concepts that have already been described by the trainer are utilizing spaced repetitions.
9. Harvard Business School publishing encourages spaced repetitions when it gives learners access to specific targeted articles from its huge library of Harvard Business Review articles and Harvard Business School cases.
10. Skillsoft – known for its off-the-shelf catalog of e-learning courses – provides its clients with spaced repetitions through its Books24/7 services, enabling learners to read further on course topics of interest to them.
11. The Monitor Group – one of the top business and management consulting firms – provides its learners with access to live consultants to answer questions or help with issues after the learners complete a rich e-learning experience.
12. Michael Belanger, PhD, Dean of the U.S. Naval Service Training Command, describes how sailors on watch get spaced learning opportunities through a simple debriefing at the end of

each shift. Watchstanders spend 15 minutes at the beginning of their shifts learning from the previous watchstander about what went on, what's currently going on, and what is expected to happen. The time is often used for questions and learning.

13. Jim Sullivan, a consultant in the restaurant industry (www.sullivision.com), promotes manager-led pre-shift meetings as a way to provide regular learning opportunities. These meetings are not meant to be preachy, but to be used to highlight new products, services, and procedures. Learning can involve roleplaying selling techniques, reminders about recent changes, quality initiatives, goal-setting, or for acknowledging previous good efforts.
14. The U. S. Federal Fire and Aviation Safety Team (FFAST) and the National Interagency Fire Center have developed a program they call "6 Minutes for Safety." For every day of the year, they provide talking points to help fire and safety leaders conduct a brief daily discussion of key issues. For example, they offer easy-to-use calendars (www.nifc.gov/sixminutes/calendar.php?month=03) that guide these discussions.
15. The Warner College of Natural Resources at Colorado State University has developed flash-based programs for PDA's (personal digital assistants) to help student naturalists learn and memorize information about fish, birds, and plant life. These programs provide both presentations and retrieval practice based on what the learner decides to use. Spacing is not built into the system, but students can utilize the system in a spaced manner on their PDA's.
16. Notepads, handheld computers, and digital voice recorders can be used for learners to gather notes or audio for later review. Reviewing notes or audio is a form of spaced repetition.
17. Supermemo is a computer-based application that provides spaced retrieval practice. In essence, Supermemo creates fully-customizable flashcards with a spacing intelligence – available for both personal computers and PDA's.
18. A college professor uses 10 quizzes throughout the semester instead of a midterm and final exam, each quiz covers 50 percent new information and 50 percent previously-learned information. Such cumulative testing prompts learners to space their relearning sessions over time.
19. Instead of chaptering learning topics – covering each topic in turn and never returning to them – a code-of-conduct course presents learners with scenario-based situations in a systematically intermingled design. Topics are introduced and then reintroduced using an expanded spacing mechanism. Not only does this enable spacing, but it keeps learners engaged, and prepares them for the unchaptered messiness of their on-the-job worlds.
20. An e-learning development company decides to do away with the course concept – the idea that learning has clear starting and stopping points. Instead, it creates small chunks of content and sells them using a subscription service. It is careful to prioritize the chunks and schedules them so that the most important and most easily forgotten points are provided more often through spaced repetitions.
21. A consumer products company decides to pull all its advertising. As an alternative, it uses small learning chunks to educate consumers about the benefits of its products. Coca-Cola hasn't pulled its advertising, but it recently utilized an online question about hydration to make the point that even caffeinated beverages produce beneficial hydration effects.

22. In the near future, as all of the following merge into one device (phones, personal digital assistants, audio, video, photo, internet, and computers), learners will be able to go to GoogleLearn.com and sign up for their weekly regimen of downloads. At first, spacing will be unintentional and generated simply by users coming across similar content. Later, learners will simply click on their phone's "LearnIt" button and select a priority level to access the information pushed back at them. Note: GoogleLearn.com is not a real service. I use it here as a metaphor.
23. Adam reads a book and then decides to read it again. Eve reads a book and underlines key passages. She skims the book every Saturday morning for the next three months. Homer reads an article and cuts it out. He puts it in a bin filled with other scraps of paper. He reviews the bin once every two weeks.
24. Reverend Elliott – instructional designer extraordinaire – preaches sermons on the same topics week after week and year after year, varying the background story somewhat, but covering the main learning points.
25. A small child listens to her mommy and daddy speaking. She hears the same words repeated over and over after spaced delays. Some words she hears after short delays. Other words take weeks to come around again. Although it may be the most difficult thing she will ever have to learn, she learns a language – she learns to understand, she learns to speak.

Case Study 1 – Midi

Spacing for Compliance Training

Midi (www.midicorp.com) is a provider of compliance and ethics solutions, including online and offline training and communication programs. Midi's first goal is to deliver learning interventions that validate a company's commitment to doing things right. But Midi wants to go further than meeting compliance standards. It wants to create learning interventions that really work to change behavior.

Compliance training isn't easy. Learners already know that they shouldn't sexually harass coworkers. They already know that they should avoid conflicts of interest. They already know to avoid insider trading. Most people know the general themes, but they don't always understand the thin gray boundary between right and wrong. People tend to consider compliance rules and ethical considerations in some workplace situations, but forget to think about them in others. Sometimes they feel the rules don't apply to them.

"It's not just about legal protection," says JC Kinnamon, PhD, VP of Instructional Design at Midi. "We want to help companies in four separate ways. We want to protect them from legal and financial repercussions. We want to help them protect their reputations and increase corporate trust – to help them improve productivity and revenues. We want to enrich and protect employees. Finally, we really believe that good compliance and ethics programs can make things better for everyone – more productivity, better communication, and a more empowering workplace."

But is Midi able to go beyond the "we just need proof that they took a course" mentality of some compliance training? Kinnamon thinks so. "One of our main goals is to keep people thinking about what they learned." Midi understands that employees forget and that once-a-year training programs just don't do enough to help learners remember.

To overcome this peculiar characteristic of human learning, Midi is beginning to offer a series of short, learning and communication vehicles that they call, Ethical Moments™. Each Ethical Moment requires about 4 minutes of a learner's time. They are delivered approximately once a month through a link emailed to learners. Midi clients subscribe to the Ethical Moments on a quarterly or monthly schedule as a way to introduce or reinforce concepts previously learned in other Midi courses.

This design accomplishes several things according to Kinnamon. "It not only keeps the information at the top of people's minds, but it also reduces forgetting." The spacing effect minimizes forgetting, but so does the actual design of the Ethical Moments. Learners receive rich-video scenarios and are engaged in realistic – and generally subtle – situations that force them to think deeply about the issues. Because of this engagement in realistic decision-making, learners are motivated to see the subject matter as important, and their memories are primed to remember and utilize the information on the job.

Case Study 2 – ZengerFolkman

Supporting Training Implementation

ZengerFolkman (www.zfco.com) is a leadership training and organizational development company founded by long-time industry leaders Jack Zenger and Joe Folkman, authors of the book *The Extraordinary Leader*. ZengerFolkman's mission is to revolutionize how leadership gets learned, how organizational development is undertaken; and to develop tools to support performance improvement. It sets itself apart by basing its approaches on empirical research and learning implementations that aim for true training transfer.

Consistent with its goal of ensuring that training is applied to the job, ZengerFolkman looked at the research on training success and determined that learners needed more support and follow-up after training. If training doesn't readily transfer to the job – if what is learned is not often implemented – then learning results are severely depressed. This nugget of truth gave birth to the ActionPlan Mapper.

The ActionPlan Mapper is a web-based hosted solution that is available 24/7. It was designed to help training participants take what they learned and apply it to their jobs. As Kelly Clayton, Product Leader for the ActionPlan Mapper, has said, "What we're trying to prevent is the Monday-morning problem. People go to a training course, they take notes, they have discussions, they get energized, they're roaring to go, but when they get back to the job on Monday, they are overwhelmed with their normal workload and the momentum for action fades to oblivion...The ActionPlan Mapper works by prodding the learners, reminding them to stay focused and keep pursuing the action items they previously resolved to accomplish."

At first glance, this type of system may not seem related to the spacing effect – it sounds more like a tool to spur on-the-job implementation; a worthy goal in and of itself. But if we consider how the human learning system works, it's clear that the ActionPlan Mapper is engendering spacing effects as well. While it is true that presenting learners with repeated information over time will create a spacing effect and improve learning results, it isn't the presentation per se that creates the cognitive outcome. Instead, it is what the presentation does – it brings the information-to-be-learned into working memory and prompts the learner to attend to that information. By reminding learners of their action plans, the ActionPlan Mapper helps learners bring information previously learned into working memory, creating a repetition and thus a spacing effect.

Because the retrieved information is likely to be directly relevant to real on-the-job tasks and issues related to the user's action plans, the spacing benefits will be quite potent. Compounding these benefits, the ActionPlan Mapper also provides feedback to learners' managers, providing another reminding mechanism to generate spacing effects. As Clayton exclaims, "Post-training learning implementations are typically hidden from managers. We wanted to make these vital processes a higher priority for learners and more visible to their managers."

Case Study 3 – Type A Learning Agency

The Ballistic Learning Effect in E-learning

Type A Learning Agency (www.typea.net) doesn't view e-learning through the same set of eyes as the rest of us. Led by CEO Anna Belyaev and Director of Instructional Design, Gretchen Hartke, Type A not only draws inspiration from within the learning-and-performance field, but also aggressively searches outside the field for wisdom to improve on-the-job learning.

One of their wildest ideas is also one of the most unique and promising ideas in e-learning. Drawing on insights from the fields of marketing and advertising – and parlaying Belyaev's background in linguistics into an understanding of how messages move through populations of individuals – Type A has hypothesized what I'm going to call a "ballistic learning effect" for e-learning. As you'll see, one of the advantages of the "ballistic learning effect" is that it creates spaced learning.

Here's how the ballistic learning effect works: Type A designs e-learning so that it generates after-learning conversations, information sharing, and reflection. Just like a ballistic missile that keeps going toward the target once launched, ballistic e-learning gives impetus to subsequent on-the-job learning.

While ballistic learning may sound crazy in comparison to traditional training and development, it draws on real-world communication examples. Belyaev and colleagues wondered why some email jokes, stories, and website recommendations reappeared in their inboxes dozens of times. They noticed how guerilla marketing campaigns energized consumers to spread the word until products became the rage. They saw how movies suddenly gained popularity – or lost it – regardless of what the critics said. They marveled at how many people knew about celebrities, sports heroes, and political sagas.

Using these examples as inspiration, Type A has developed several e-learning paradigms that engender after-learning learning. They spread learning sessions over time to ensure that learners have a reason to talk about what they're learning. Instead of learning resulting in, "been there, done that," it becomes "hey, what do you think about that?" They invite high-visibility people within a company to send emails to the learners during the span of learning. Type A isn't afraid to utilize controversy, create new slogans to stimulate thought, develop popular-magazine-like quick-and-dirty diagnostic tools ("What's your innovation style?") to get people sharing, to use edgy humor, and prompt leadership-like "calls to action" to create focus and motivation on real work. They have even combined these ideas into an e-learning paradigm they call the "e-learning campaign" – a design that weaves e-learning into the everyday fabric of people's work.

The aim of these ballistic-learning effects is stickiness, sharing, and learning-related activity. In some sense, with these methods, The Type A Learning Agency prompts its learners to create their own spacing effects.

Case Study 4 – Allen Interactions

Multiple Spaced Practice Opportunities

Allen Interactions (www.alleni.com), founded by e-learning guru Michael Allen, develops custom e-learning to achieve on-the-job performance improvement. To create such behavior change, Allen's design teams go beyond simple presentations of learning material. One of their overriding design imperatives is to put learners into realistic situations and provide them with a generous number of practice opportunities.

For example, Allen designed a program for Union Bank of California that presents learners with a brief introduction and then gives them practice determining whether eight checks are officially negotiable. When learners make a mistake, they get feedback and have to figure out why they made a mistake. After processing a few other checks, they get a second chance on a check that has similar issues to the one they had previously gotten wrong. Once learners have successfully dealt with all the different types of check-negotiation difficulties, they are provided with a ten-item test. Spaced repetitions are provided at many points in the design. First, the concepts are presented. Then learners get practice with feedback that forces them to process the information again. They then get additional practice on the checks they didn't get correct. On the final test they get another set of spaced repetitions.

Allen used a similar design to teach learners what ingredients are included in different types of flour (for example, bread, wheat, or pastry flour). Learners have to decide which type of wheat to use, whether to filter out bran and germ, and whether to include baking powder and salt. A conveyor belt pushes different empty flour bags under the flour grinder. Each bag is labeled for a different type of flour. If a bag of cake flour is needed, for example, learners have to choose soft spring wheat and filter out the bran and germ. When learners grind a bag of flour correctly, they get a second chance after a few more bags – just to make sure they weren't guessing. Later, after an even longer spacing, they get other chances to grind that flour properly – another opportunity for retrieval practice. When learners grind flour incorrectly, they get another chance after a short spaced delay. Once they get it correct, they will receive expanding spacings to strengthen retention.

In keeping with their emphasis on authentic spaced practice opportunities, a few years ago Allen Interactions developed an authoring tool called the DialogCoach. It provides learners with a tiered system of spaced practice, gradually reducing the number of hints, as learners try to retrieve difficult verbal responses from memory. The DialogCoach has the capability – through computer-based natural-language processing – to evaluate what learners say and give feedback on their statements. The brilliance of DialogCoach is that it puts learners in realistic situations, has them respond as if they are in real-world customer-service situations, gives them feedback, and provides spaced practice over time.

One of Allen's goals is to “create e-learning that helps people do the right thing at the right time.” They do this by providing multiple spaced repetitions of retrieval practice.

Case Study 5 – Skillsoft

The Spacing Effect of Learning Portals

Skillsoft (www.skillsoft.com) is known for having one of the largest catalogs of e-learning courses in the world and for offering online access to books through its Books24x7 brand. One of its latest innovations, “Knowledge-Center,” is in development. These learning portals are a collection of resources that will enable learners to reinforce, enrich, and update their learning.

For example, Skillsoft has about 30 courses that teach concepts related to the Visual Basic programming language and related skills. Clients can purchase the whole Visual- Basic bundle or choose a subset. Regardless of how many courses a learner takes, with the Visual-Basic Knowledge Center, learners will get the option of continuing their learning after they’ve completed their chosen course work.

Where general-purpose portals offer computer users access to lots of information, learning portals are specifically focused on providing resources related to well-defined areas. “Learning portals can be distinguished based on topic area, courses, learner groups, or any set of criteria that makes sense for learning,” says Sally Hovis, Vice President of Learning Design for Skillsoft.

The Visual-Basic Knowledge Center will include many resources, including downloads of books on Visual Basic through Books24x7, targeted reference materials, information that gets refreshed and updated to keep pace with software and practice changes, access to experts who can answer questions, highlighted topics, test-certification preparation updates, coding practice exercises, and even a practice example that can evaluate a learner’s simulated coding performance and provide feedback.

The ramifications for the spacing effect are many. While Skillsoft’s vast array of courses may keep learners refreshed and busy for long stretches of time, the Knowledge-Center concept enables learners to search for specific information and reinforce their learning on a periodic basis. This is especially relevant in an information-technology area where changes in software and practices accelerate from year to year.

These learning portals will provide different recommendations to different learners. For experienced learners, the focus will be on specialized skill sets, information updates, and just-when-needed help. For novice learners, a learning path will be recommended that provides a breadth of experience and lots of practice. For learners working toward ongoing certification, simulated certification-exam test-taking will be provided and information will be recommended to help prepare learners to pass certification exams.

As Hovis points out, “This is not only about spacing and reinforcement – though those things are critical – it’s also about enrichment and advanced learning. Nothing helps people remember better than learning something in-depth.”

Case Study 6 – Work-Learning Research

Stretching Consultative Learning Engagements

Work-Learning Research (www.work-learning.com) is my company. We compile research from the world's preeminent refereed journals and share that information in research reports, workshops, and speaking engagements. We provide research-based consulting services to instructional designers, e-learning developers, and training specialists. We provide learning audits and evaluation services at LearningAudit.com.

When I started doing workshops and consulting, I soon became frustrated that my clients – though greatly appreciative of my efforts and grateful to have validated research-based information – would forget what I had taught them and would create designs that only partially implemented the recommendations they had learned. It was very difficult for me to have to explain that their new designs still weren't quite as effective as they might be. Some would say, "But didn't you tell us to do it that way?"

Their forgetting was my failure. Forgetting is going to happen, but it's my responsibility, as the instructional professional, to minimize forgetting as much as possible.

Later, I developed an online course on e-learning, called Leveraging E-learning, which helped e-learning developers utilize fundamental learning factors. Its learning methods included online presentations, reading assignments, projects, scenario-based decision-making, job aids, and a discussion board that facilitated online discussions. The course was spread out over five weeks, with an additional four weeks where learners could contact me to ask questions or get recommendations. The course seemed like an ideal implementation of spaced learning, but it had one fatal flaw. It required an exhaustive effort on the instructor's part – an effort that was not sustainable in the long run.

My latest attempt in utilizing spaced learning is a bit more modest, but so far, the results are promising. In general, I look for consulting clients who understand the need for a long-term relationship. Such relationships ensure that learning can be spaced and that feedback can be delivered when needed. Even when a recurring engagement isn't desired, three or four days are beneficial – as compared with one-day walk-throughs.

Specifically, I've had success using consulting engagements that begin with a short, high-intensity workshop on the key concepts from the learning research. With this as an introduction, further learning involves discussions about clients' previous efforts, brainstorming on current client projects or on hypothetical design initiatives, and conversations based on formal learning audits of clients' instructional interventions. Clients have also requested that I challenge them with initiatives for them to work on after I leave their premises, further expanding the spacing of learning.

I'm still learning how to implement spaced learning. My goal is to see spacing as a valuable tool, try it when it seems appropriate, and tweak it to make it work better.

Questions to Test Your Understanding

Let me make a recommendation for how to utilize these questions (based on the learning research, of course). Wait a week or a month or so before answering these questions. Answer each question before looking below to see what the answer is. In this way, you'll give yourself spaced repetitions of retrieval practice. After answering all the questions, restudy the previous material, or read the subsequent material on the research details.

- 1. An instructional designer wants to develop a course for sales people to help them improve their presentation skills. Fifteen hours of class are required. Which schedule of learning will produce the most highly-skilled presenters?**

- A. One week, eight hours on Monday, seven hours on Friday.
- B. One week, Monday through Friday, three hours each day.
- C. Two weeks, Monday through Friday, one and a half hours each day.
- D. All the designs above will be equally effective.
- E. Choices B and C will produce similar results.

The correct answer is the third letter in this sequence: EACEBDA

The person whose learning is spaced more widely over time will be better able to retrieve information from memory, and hence, will perform the best.

- 2. The first Monday in March is a big day for Mabel because the Corporate efficiency monitor will be evaluating her skills as an equipment operator. Mabel is nervous because she's going to be tested on a new machine – one that she hasn't been able to practice on yet. Today is February 1st and fortunately, Mabel's boss has agreed to let her use the new machine after-hours to practice (with paid overtime or comp time, of course). Mabel has decided to practice for eight hours altogether. When should Mabel schedule her practice if her goal is to do well when being evaluated on the first Monday in March?**

- A. Every Monday and Friday in February for one hour.
- B. Every Monday in February for one hour, and four hours on the Friday before the first Monday in March.
- C. Two hours on the Friday before the first Monday in March, two hours on that Saturday, and four hours on that Sunday.

The correct answer is the fifth letter in this sequence: ABCBCAB

When the test of performance is given soon after learning, short spacings will often outperform longer spacings.

- 3. Peter is learning Spanish vocabulary words. To aid his practice, he has written the Spanish word on one side of an index card and the English synonym on the other. He tests his knowledge by looking at one side of the card and trying to remember the other side. Peter has randomly divided the cards into four sets of five cards each. How should Peter study his words?**

- A. Study Set 1, then Set 2, then Set 3, then Set 4, then Set 1, then Set 2, then Set 3, then Set 4, then Set 1, then Set 2, then Set 3, then Set 4.

- B. Study Set 1, then Set 2, then Set 1, then Set 2, then Set 1, then Set 2, then Set 3, then Set 4, then Set 3, then Set 4, then Set 3, then Set 4.
- C. Both methods will produce similar results.

The correct answer is the second letter in this sequence: AABCBCB

Inserting other items between repetitions produces superior recall of items that are repeated. The more intervening items, the better, up to a point of diminishing improvement.

- 4. Word-processing trainees are taught a variety of word-processing procedures and are then given practice exercises on each procedure. To ensure that they are fully capable of accomplishing a procedure, they are asked to repeat the procedure three times. Which of the following methods will produce the best performance?**

- A. Using a different word-processing document in each practice exercise.
- B. Using the same word-processing document in each practice exercise.
- C. Both methods will produce equally superior performance.

The correct answer is the third letter in this sequence: ABACACB

When learning materials are repeated immediately, they will be better learned if the material is slightly altered rather than if it is repeated verbatim.

- 5. An advanced chemical engineering course is offered online. Lessons are designed to follow-up on previous lessons. Exercises are cumulative, requiring knowledge from previous lessons. There are eight lessons altogether. When six months have passed after their successful course completion, which of the learners will remember the most?**

- A. Those who completed the course in two weeks.
- B. Those who worked on the course every Monday night for eight weeks.
- C. Those who worked on the course every other week or so, when they got a chance, completing the course in four months.
- D. All of the above will produce equal results.

The correct answer is the fifth letter in this sequence: DABDCAB

To produce the best long-term retention, it is generally desirable to have the longest spacing between learning events.

- 6. An Internet training provider is designing a course for a customer. Because the customer is demanding real learning results, they've decided to use spacing to remind their learners of the main points of the course. They plan to send five short, insightful, and interesting emails after the course, each reiterating the main points in a manner that varies from one email to another. Assuming that the learners read all the emails with a high level of attention, which of the following designs will produce the best long-term retention? In other words, what is the best way to send the five emails?**

A.

Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
			1			
			2			
			3			
			4			
			5			

B.

Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
		1		2		
			3			
					4	
			5			

C. Both the sequences will produce equal memory and performance results.

The correct answer is the second letter in this sequence: ACCBABB

Expanded spacings and equal spacings are both equally effective in producing retention in cases where learning materials are presented to learners.

7. High-powered executives are trained in a variety of skills. They are provided with five one-day courses that are spaced days, weeks, or months apart. Because the executives are very busy – and their time is extremely valuable – there is no overlap in the learning points of each class. Which spacing schedule will produce the greatest long-term learning? In other words, which spacing is likely to produce learning that will be remembered two or three months from now?

- A. Each class is separated by two or three days.
- B. Each class is separated by one week.
- C. Each class is separated by one month.
- D. All of the above will produce equal results.

The correct answer is the third letter in this sequence: ABDCBDB

The spacing effect typically produces its benefits when repetitions are spaced over time. In this case, the learning material was not repeated, so no spacing effect should be observed.

8. George is learning a series of new needlepoint techniques by reading “Needlepoint For The Really Smart.” Which of the following is the best strategy to remember each technique?

- A. Reading the material for each procedure once, immediately reading it a second time, and then practicing each procedure once.
- B. Reading the material for each procedure once, and then practicing each procedure once.
- C. Both strategies will produce equal results.

The correct answer is the fourth letter in this sequence: BCCABAB

Immediate repetitions, although not as effective in creating learning as spaced repetitions, are generally more effective than having no repetitions at all.

9. An equipment repair technician needs to know 75 repairs to perform the job. Only 20 of the repairs are encountered every month. The others may not be encountered for periods of six months to a year. A five-day course – taught on five consecutive Saturdays – is developed to teach all the repairs. 15 repairs are taught each Saturday. Which design will produce the best long-term learning?

- A. Having a review of the previous week's 15 repairs at the beginning of every class.
- B. Instead of using the class time for review, using it for more detailed instruction of the various repairs.
- C. Both strategies will produce equal results.

The correct answer is the sixth letter in this sequence: ABCABCB

To produce long-term retention for complex or lengthy learning material, more than one repetition will likely be needed.

10. An instructional designer decides that he doesn't have time to repeat the learning material in the course, but that he will encourage the use of repetitions by having students prepare for a follow-up exam. Which set of instructions will produce the best learning?

- A. Telling the learners to study in their normal way.
- B. Telling the learners to use spaced studying methods.
- C. Telling the learners to use spaced studying methods, and then sending them emails to remind them to study at periodic intervals.
- D. All three strategies will produce equal results.

The correct answer is the sixth letter in this sequence: ABCDACB

Although suggesting the use of spaced learning will have more of an impact than allowing learners to study as they usually do, providing them with the suggestion and the reminders will likely be more effective.

Research Support for the Spacing Effect

Research on the spacing effect has a long history. As early as 1885 Ebbinghaus (1885/1913) published his classic book on memory, in which he showed, among other things, that spaced learning is more effective than massed learning. Over 300 studies were done on the spacing effect in the 20th Century (Bruce and Bahrick, 1992), and at regular intervals, some experimental psychologist reviews the research on the spacing effect and announces that it is one of the most robust findings in all of psychology (e.g., Donovan & Radosovich, 1999; Lee & Genovese, 1988; Ruch, 1928; Cain & Willey, 1939; Melton, 1970; Crowder, 1976; Hintzman, 1974; Glenberg, 1979; Rea & Modigliani, 1988; Dempster, 1988, 1989; 1996).

The spacing effect is well documented in the research. Bahrick and Hall's (2005) comment, quoted earlier, that "the spacing effect is one of the oldest and best documented phenomena in the history of learning and memory research," is indicative of its strength. Surprisingly, while it is one of the best documented phenomena, the spacing effect is also one of the least known or appreciated in the fields of instructional design and education (Dempster, 1988).

The spacing effect has been found in a wide array of experimental situations, illustrating its general applicability. It has been found in numerous highly-controlled list-learning experiments (e.g., Melton, 1970; Verhoeijen, Rikers, & Schmidt, 2005). It has also been found in classroom situations (e.g., Pyle, 1913, Austin, 1921), in vocabulary learning (e.g., Dempster, 1987a), in learning vocabulary in a foreign language (e.g., Bahrick, 1979; Bahrick & Phelps, 1987; Bahrick, Bahrick, Bahrick, & Bahrick, 1993), in programmed instruction (e.g., Reynolds & Glaser, 1964), in multimedia simulations (e.g., Shebilske, Goettl, Corrington, and Day, 1999), in reading (e.g., Krug, Davis, & Glover, 1990; Rothkopf & Coke, 1963), in using chapter summaries (Reder & Anderson, 1982), in advertising research (e.g., Singh, Mishra, Bendapudi, and Linville, 1994) and even in remembering the street names where one went to college (Bahrick, 1979). Similarly, the spacing effect has been found with young adults, old adults, and children as young as preschool (for some age diversity in spacing see, Rea & Modigliani, 1987; Toppino (1991); Singh, Mishra, Bendapudi, & Linville, 1994; Kausler, Wiley, & Phillips, 1990).

Researchers have compared differences in relatively long lags (measured in days) and relatively short lags (measured in seconds). 14-day lags between repetitions have been compared to 28-day lags and 56-day lags (e.g., Bahrick, Bahrick, Bahrick, & Bahrick, 1993). Zero-second lags have been compared with 1.6-second lags, 3.2-second lags, 6.4-second lags, 16-second lags, and 32-second lags (Melton, 1970).

Research on the spacing effect continues – not because there is a need to prove its value, but to determine boundary conditions and to discern its underlying causes – see, for example, Bahrick & Hall, 2005; Carpenter & DeLosh (2005); Appleton-Knapp, Bjork, & Wickens (2005); Pavlik & Anderson, (2005); Son (2004).

Examples of Typical Spacing Research

Let me share with you some examples of the research done on the spacing effect. Although a short list, it provides an understanding of the kind of work that informs the recommendations put forth earlier.

Gordon (1925) had learners attempt to remember the Athenian Oath as she read it out loud. In her second experiment, she repeated the oath three times in succession on one day (unspaced), or read the oath aloud once, waited a week and read it again, and then waited another week and read it a third time (spaced). She tested these learners immediately after the third reading and then again after three weeks. The experiment showed that, for the immediate test, the unspaced repetitions produced better retention by 24%, but for the more important delayed test (after a wait of three weeks following the final recitation) that spaced repetitions produced better retention by 23%.

In a simulated pilot-training experiment, Shebilske, Goettl, Corrington, and Day (1999) found that learners who had two learning opportunities spaced at ten days outperformed those who had them spaced at two days by 49% on immediate tests of retention and 42% on tests that were delayed one week.

The Bahrick family (Bahrick, Bahrick, Bahrick, & Bahrick, 1993) found that retaining foreign-language vocabulary over five years was improved 19% when the learning was spaced 28 days apart compared with 14 days, and improved 12% when spaced at 56 days rather than 28 days (the 14-day to 56-day improvement was 34 percent). After an amazing five-year retention period, in which each learner had to remember 300 words after studying them either 13 or 26 times, the 14-day spacing led to recall of 49.8 percent of the words, 28-day spacing led to 59.3 percent recall, and 56-day spacing led to 66.5 percent recall. Examined another way, Bahrick, Bahrick, Bahrick, and Bahrick (1993) demonstrated that spacing can reduce the number of repetitions needed. For example, they found that 13 repetitions spaced at 56 days yielded the same level of retention as 26 repetitions spaced at 14 days!!

Krug, Davis, and Glover (1990) asked learners to study a written essay and then gave them an additional five minutes to study the passage either immediately (unspaced) or in one week (spaced). Across three experiments, those in the spaced conditions remembered 40, 38, and 30 percent more of the essay than those in the unspaced conditions.

Singh, Mishra, Bendapudi, and Linville (1994) found that television commercials that were repeated after four intervening commercials (spaced) produced better memory the following day than commercials that were repeated with only one intervening commercial (less-spaced) by 18% for younger adults and 160% for older adults.

Bloom and Shuell (1981) presented learners with 3 distinct 10-minute exercises to help them learn the same 20 French vocabulary words. The 10-minute exercises were

presented back-to-back or spaced over three days. The spaced learning produced only 5% improvement on an immediate test, but 35% improvement on a surprise test given 7 days later.

Roediger and Challis (1992) presented learners with lists of words with items repeated after zero intervening items (massed repetitions) or after 9, 10, 21, or 31 intervening items, depending on the experiment. In measuring free recall in 3 different experiments (Experiments 2, 3, and 4), the

spaced repetitions – when they were exact repetitions – produced improvements over massed repetitions of 16%, 29%, and 32%.

Cull (2005) used a pair-associate paradigm to determine whether expanding and uniform spacings of retrieval practice were better than massed spacings. In four separate experiments, Cull had learners learn word pairs consisting of an initial uncommon word and a second common word (bairn-print is an example of the types of word pairs used). Learners initially learned the word pairs. They were then presented with three or more repetitions of the same word pair that either (a) presented the first word alone prompting learners to recall the second word after which they got feedback, (b) presented the first word alone prompting recall with no feedback, or (c) presenting both words together. Over four separate experiments using widely varying spacing intervals (from seconds and minutes in Experiments 1 and 2 to two or three days in Experiments 3 and 4), the average learning improvement due to spacing was 82 percent.

Rothkopf and Coke (1963) had learners learn information from short sentences. When the sentences were repeated immediately, those repetitions produced better recall by about 15% than non-repeated sentences (those presented only once). But if the repetition for these sentences was repeated after other unrelated sentences had been presented, improvements in recall more than doubled to 33%.

In a series of experiments simulating the effects of print advertisements, Appleton- Knapp, Bjork, and Wickens (2005) presented people with a series of ads and varied the number of times these ads were presented. Five to eight minutes later they asked people whether they could remember the name of the brand associated with a particular advertising slogan. What they found was that ads repeated verbatim showed definite spacing effects, with immediate repetitions producing an average (over Experiments 1, 2, and 4) of 20% recall, repetitions after 20 seconds producing 33% recall, repetitions after 40 seconds producing 41% recall, and 10-minute repetitions producing 44% recall.

Immediate Repetitions are Not Very Effective

Immediate repetitions are much less effective than repetitions given after short or long delays. In fact, it appears from the research that learners' cognitive systems simply shift into neutral when they are faced with immediate repetitions. Whether through conscious decision-making or some sort of subconscious perceptual shutdown, learners process immediate repetitions with very little intensity. The evidence for this has been found in

list-learning studies that compared zero intervening items between repetitions to two, four, twenty, or more intervening items (Challis, 1993; Greene, 1989; Melton, 1970; Russo, Parkin, Taylor, & Wilks, 1998). It has been found in studies that compare immediate repetitions to repetitions that are delayed for periods of one hour, one day, one week or more (Krug, Davis, & Glover, 1990; Bahrick & Phelps, 1987). Immediate repetitions have been shown to depress attentive processing (Rothkopf, 1968).

Immediate repetitions have also been shown to lower rates of physiological responding in learners (Wagner, Desmond, Demb, Glover, & Gabrieli, 1997; Hyoenae & Niemi, 1990; Magliero, 1983). Wagner and colleagues (1997), using functional MRI techniques, found that repetitions “decreased activation in left inferior prefrontal cortex (LIPC).” Hyönä and Niemi (1990) found that repeated readings decreased total eye movement fixation time, average fixation duration, number

of progressive fixations, and the number of regressions, while increasing saccade lengths – metrics associated with diminished learner responsiveness. Magliero (1983) found pupil dilations decreased when words were repeated, but much less so with spaced repetitions than with immediate repetitions.

Immediate repetitions pale in comparison to spaced repetitions, but they generally outperform no repetitions at all. This is true for the learning of very short items, like words or names (Landauer & Bjork, 1978; Glenberg & Lehmann, 1980) and for longer items like sentences and paragraphs (Bromage & Mayer, 1986; Kiewra, Mayer, Christensen, Kim, & Risch, 1991; Thios, 1972), and for both short items and long items (Cull, Shaughnessy, & Zechmeister, 1996). So, although immediate repetitions are the least useful type of repetition, they produce more learning than having no repetitions.

Improving the Effectiveness of Immediate Repetitions

Immediate massed repetitions can sometimes be made as effective in creating learning as spaced repetitions. If massed repetitions are paraphrased or varied in some way instead of being identical to the first presentation, they can sometimes reach the levels of spaced learning (Dellarosa & Bourne, 1985; Glover and Corkill, 1987; Krug, Davis, and Glover, 1990; Thios, 1972; Roediger and Challis, Experiment 4, 1992; Appleton-Knapp, Bjork, & Wickens, 2005).

Dellarosa and Bourne (1985) repeated sentences exactly or in a form that preserved the meaning but used slightly different words. For example, the sentence, “They turned up the street, where they had a clear view of the lake” was sometimes repeated in its “gist” form as, “The lake became clearly visible to them as they turned up the street.” The results of the experiment were astounding. When the learners were given the repeated sentences back-to-back, the sentence repeated exactly produced scores of about 18% on a sentence reproduction task, whereas repeating the sentence with the gist form produced scores of about 41%, a whopping 127 percent improvement over the exact repetition (with an effect size of .39)! In a second experiment, Dellarosa and Bourne (1985) showed that repeating sentences exactly, but changing the speaker of the sentence improved

performance by 162% (with an effect size of 0.39). Both experiments show that the performance decrements associated with massed repetitions can be overcome by varying the form in which the repetition is delivered. Krug, Davis, and Glover (1990) replicated Dellarosa and Bourne (1985) but had people reread passages not sentences. Durgunoğlu and Roediger (1987) found that, for free recall, reading a word once in Spanish and once in English produced better recall (.35) than reading the word twice in English (.16) or twice in Spanish (.23). Glanzer and Duarte (1971) found similar results. Both papers show that varying the language modality of the repetition helps subsequent retention when learners are faced with massed repetitions.

Note that variations in massed repetitions don’t always produce better performance (Wells and Kirsner, 1974; Marmurek, Holt, and Coe, 1978; Rothkopf & Coke, 1966). Note also that bilingual repetitions don’t always produce better results. Durgunoğlu, Mir, and Ariño-Martí (1993) found positive results in Experiment 2 but not in Experiment 3.

Finally, note that even though exercises are changed, massed practice can still produce worse performance on a long-term test of retention (Bloom & Shuell, 1981). Nevertheless, most studies using massed repetitions show some advantage for variable repetitions, and only very rare deficits

caused by varying the repetitions. The caveat here is that, unfortunately, most studies use immediate tests of retention, which are less representative of training and performance situations and are more likely to hide decrements in retention that may be associated with variable repetitions.

Shorter Spacings Can Be Better for Short Retrieval Intervals

Short repetition delays are often equal or better than longer repetition delays for short retention periods (for example, when testing is immediate or the performance situation is imminent – this is the cramming effect). Long repetition delays are better for long retention periods (Gordon, 1925; Glenberg & Lehmann, 1980; Singh, Mishra, Bendapudi, & Linville, 1994; Austin, 1921; Bloom & Shuell, 1981; Bahrick, Bahrick, Bahrick, & Bahrick, 1993; Bahrick, 1979). Note however that at least a few experiments have shown that longer spacings are better even when the retention interval is short (e.g., Appleton- Knapp, Bjork, & Wickens, 2005; Kahana & Howard; Rothkopf & Coke, 1963). For example, in an experiment utilizing a complex-skill task, long learning delays outperformed short learning delays, regardless of the length of the retention interval (Shebilske, Goettl, Corrington, & Day, 1999).

Using Expanded Spacings between Retrieval-Practice Repetitions

Some researchers have found that gradually increasing spacing delays between retrieval-practice opportunities (the kind that don't provide corrective feedback) is as effective as, or even more effective than, just having long lags between retrieval opportunities (Landauer & Bjork, 1978; Rea & Modigliani, 1985; Morris, Fritz, Jackson, Nichol, &

Roberts, 2005). For example, being tested with lags of 1, 3, and then 5 days (Monday then Tuesday then Friday then the following Wednesday) may produce similar learning performance to being tested with lags of 3, 3, and 3 days (Monday then Thursday then Sunday then Wednesday).

Unfortunately, conflicting research results and the need for more research make it difficult to make instructional-design recommendations at this time (Carpenter & DeLosh, 2005). For example, Cull (2000) found no added advantage for expanded spacings. Carpenter and DeLosh (2005) found an advantage for consistent spacings in one experiment and an advantage for expanded spacings in another.

It is important to note that expanded spacings only have theoretical support (in being potentially better than consistent spacings) for retrieval practice opportunities that don't provide corrective feedback. They are not thought to be better than consistent spacings for simple presentation-type repetitions, nor are they implicated for retrieval-practice opportunities that provide feedback. For example, Cull, Shaughnessy, and Zeichmeister (1996) found that expanding retrieval-practice spacings outperformed consistent spacings in four experiments where no corrective feedback was given, but when they added corrective feedback in a fifth experiment, expanding and consistent spacings produced identical results.

Because more research is needed – in relation to expanded spacings for retrieval-practice without corrective feedback – we will have to wait for definitive guidance. Fortunately, most instructional designs provide feedback, making the research debate less important.

Still, we are left with the question of whether expanded spacings might be worth doing sometimes. While research hasn't yet uncovered the answer, three points should be considered in our thinking. First, expanded spacings may not produce better results than consistent spacings, but the limited data available suggests that their results aren't consistently worse. Second, expanded spacings are often more difficult to implement than consistent spacings. Third, truly realistic learning, because it tends to require relatively longer memory retention – the kind that in theory may benefit from expanded spacings – may yet show benefits from expanded retrieval-practice repetitions.

Several Repetitions May Be Needed

When we examine the most realistic experiments (in relation to typical training situations), especially experiments that ask learners to remember information for longer than a few days, we find that most of the successful experiments used at least 3 and often more repetitions. For example, Bahrnick (1979) used 3 and 6 repetitions. Bahrnick, Bahrnick, Bahrnick, and Bahrnick (1993) used 13 and 26 repetitions. Bahrnick and Phelps (1987) used 6 to 9 repetitions. Smith and Rothkopf (1984) used 4 repetitions. Gordon (1925) gave her students 3 and 6 repetitions. Shebilske, Goettl, Corrington, and Day (1999), using a complex pilot-training-type task, gave learners 10 lessons of 8 practice sessions, each for

a combined total of 80 sessions before testing began. This is not to say that all realistic experiments using only a single repetition have produced non-significant results. Some have (e.g., Glenberg & Lehnmann, 1980), but others have failed to reach statistical significance even though the results tended toward a spacing effect (Ausubel, 1966). The point of this paragraph is that realistic materials in realistic learning situations may require multiple repetitions, and hence, the benefits of spacing may not accrue in these situations unless several repetitions are used.

What Causes the Spacing Effect?

It is now time to turn our attention to the causes of the spacing effect. Three reasons for the spacing effect seem to predominate in the research literature (see Hintzman, 1974, 1976; Dempster, 1996; Greene, 1989; Challis, 1993; Russo, Parkin, Taylor & Wilks, 1998). These can be called (1) encoding variability, (2) proficient processing, and (3) learning-strategy adaptation.

The first theoretical rationale for the spacing effect involves the notion of encoding variability. What in the heck is “encoding” you’re probably asking. When we are learning something, we are said to be encoding that knowledge into our memory storage. Encoding is the process of taking information and recording it in memory. Every piece of knowledge stored in memory is connected to other pieces of information in a web-like arrangement. The more connections a piece of information has, the more likely it will be retrieved when it is required. Thus, if a piece of information is learned in several different ways or at several different times, it is likely to have more connecting pathways than if it is learned under less diverse conditions (Smith, Glenberg, Bjork, 1978; Smith and Rothkopf, 1984; Smith, 1982). When encoding conditions are variable, learning performance improves (Glenberg, 1979; Melton, 1970; Greene, 1989). In this view, spacing places learners into varying contexts for each spaced repetition, thus prompting variable encoding and more retrieval routes for later remembering.

The second reason regularly cited as a cause for the spacing effect is the deficient processing of repetitions during massed learning – and in comparison the relatively proficient processing of spaced repetitions. Whether through boredom, fatigue, habituation (Hintzman, 1974; Challis, 1993; Russo, Parkin, Taylor & Wilks, 1998; Dellarosa & Bourne, 1985), or conscious learning strategies (Rothkopf, 1968; Greene, 1989), it is argued that repetitions during massed learning are not processed (thought about) as deeply as the original learning. Thus, for example, where one original and one spaced repetition may be worth two learning events, one original and one immediate massed repetition may be worth only one or one-and-a-half learning events. Where the spaced repetition gets fully processed, the massed repetition is ignored or given only a cursory level of attention.

The third explanation of the spacing effect is that retrieval failures spur learners to process information more intensely and more elaborately. Bahrick (1979, p. 301), in his

classic report, hypothesized that learners who are prompted to revisit learning material over long spacings develop strategies to help them retrieve the information – strategies that don't rely on tenuous cues that may be available only in the short term. Recently, Bahrick and Hall (2005) confirmed this theoretical perspective by finding that when learners experienced a retrieval failure on their previous recall attempt, they subsequently increased their study time by a whopping 268% on the failed item, in comparison to items they had previously recalled correctly. Learners didn't just spend more time; they also utilized more effective encoding strategies. One-day spacings prompted 147% more use of good encoding strategies (visual or verbal elaborations) than massed repetitions, and 14-day spacings prompted 160% more good encoding strategies than the massed repetitions. In two experiments, the longer spacings produced better retrieval by 150% and 60%, respectively.

Although these three explanations are the leading theoretical explanation of the spacing effect, authors have cited numerous other candidate theories in their review sections (for recent reviews see Dempster, 1989, 1996; Shebilske, Goettl, Corrington, and Day, 1999). For example, Shebilske, Goettl, Corrington, and Day (1999) pointed out that repetitions spaced over 24 hours may produce memory improvement because sleep acts as a facilitator of memory (for research studies see Koulack, 1997; Plihal & Born, 1997, 1999; for a review, see Antrobus & Bertini, 1992).

It may be more realistic to talk about several spacing effects and their different causes (an idea suggested by Hintzman, 1987, in a personal communication to Dempster, 1989; and perhaps elsewhere as well). For example, immediate repetitions may have different cognitive effects than short-delay repetitions. Long spacings may prompt learners to encode information in a way that makes it retrievable in the long run. Repetitions with intervening learning items might produce different memory stores than repetitions spaced apart in time. Repetitions interposed with sleep may differ from repetitions repeated without intervening sleep. Despite these other theoretical options, it appears likely that variable encoding improves learning in spaced situations and deficient processing of massed repetitions depresses learning in massed learning situations. Furthermore, although more research needs to be done to smooth out the ragged edges in our search for the ultimate causes of the spacing effect, the practical conclusion still remains. Spaced repetitions produce better long-term retention in most situations.

What Do Learners Prefer?

One of the most troublesome research findings in the repetition and spacing area is that most learners feel that massed learning produces better results than spaced learning. Zechmeister and Shaughnessy (1980) discovered that learners who receive massed repetitions have an exaggerated sense of their ability to remember the repeated information. Massed repetitions give learners a false sense that they know the material. Given this false sense, learners often stop attending to the learning material in a way that facilitates retention. They think they know it, so they move on to other activities.

Unfortunately, this tendency can be exacerbated by instructors' tendencies to underestimate the time learners need to fully grasp the material and the difficulty they have in performing new tasks (Hinds, 1999).

Equally as troubling is that those of us who facilitate and design learning events may also prefer massed repetitions, because we think that they create the most learning. Rothkopf (1963) asked a group of educators to evaluate different text designs, some that utilized massed repetitions and some that utilized spaced repetitions. The educators predicted that the massed repetitions would produce 15% more learning than the spaced repetitions, when in actuality the massed repetitions produced 36% less learning than the spaced repetitions. Schmidt and Bjork (1992) warned that instructional designers may gravitate toward designs (such as massed practice) that make learners feel good about their progress – even when those designs hurt long-term learning. Dempster (1987b; 1988; 1989), apparently exasperated at the failure of trainers, educators, and instructional designers to utilize the results of research on learning, led a mini-crusade to encourage the spacing of repetitions. The upshot of this discussion is that, although spaced learning is a highly effective learning method, both learners and designers of learning have had a tendency to avoid its use. On a more hopeful note, when learners are encouraged to use spaced learning methods in their own memorization efforts, they have done so (Landauer & Ross, 1977).

Spacing Doesn't Always Improve Performance

Of course, spacing doesn't always improve performance. We've already discussed how massed repetitions may be better when the performance situation is imminent. In addition, some research has not found the expected spacing effects. For example, Toppino and Gracen (1985) presented learners with lists of words with differing numbers of intervening items. In nine experiments, some using the same learning materials that Glenberg (1977) used in research demonstrating spacing effects, Toppino and Gracen found no evidence for a spacing effect. Elmes, Dye, and Herdelin (1983) found spacing effects, but not when they used lists of words that had similar affective connotations (all "good" words or all "bad" words). Similarly, Kahana and Greene (1993) found no spacing effect when lists contained only words that had "high interstimulus semantic similarity" (e.g., all the list words were four-footed animals). Finally, Ash (1950) did essentially the same experiment as Smith and Rothkopf (1984), but unlike these researchers, Ash found no difference between massed and spaced learning. Experimental results that show no spacing effect could be due to chance occurrences. It is more likely, however, that results that indicate no spacing effect represent boundary conditions on the spacing effect that research has yet to fully delineate.

Spaced Retrieval Practice Better Than Spaced Presentation.

In comparing retrieval practice to mere presentation, retrieval practice generally produces much greater benefits (Nungester & Duchastel, 1982; Hogan & Kintsch, 1971; Cuddy & Jacoby, 1982; Kuo & Hirshman, 1996; Izawa, 1992; Allen, Mahler, & Estes, 1969; Jones, 1923-1924). This is especially true when retrieval practice is accompanied by feedback.

The benefits of retrieval practice are also found when retrieval practice opportunities involve spaced repetitions (Cull, 2000). Similarly, Morris, Fritz, Jackson, Nichol, and Roberts (2005) and Morris and Fritz (2000) demonstrated that an expanding sequence of testing is better than an expanding sequence of study opportunities.

Non-Spacing Benefits.

Repetitions have been found to create other effects besides just better memory. Research has shown that repetitions can make ideas more persuasive (Cacioppo & Petty, 1989; 1979; Claypool, Mackie, Garcia-Marques, McIntosh, Udal, 2004; Maslow, 1937) and products more desirable (Nordhielm, 2002; Cox & Cox, 2002). These results aren't always straightforward. For example, repeated exposures tend to push people to more extreme attitudes, whether positive or negative (Downing, Judd, & Brauer, 1992). If we assume that most training materials produce positive-trending attitudes toward the information learned, we would expect spaced repetitions to increase positive attitudes.

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