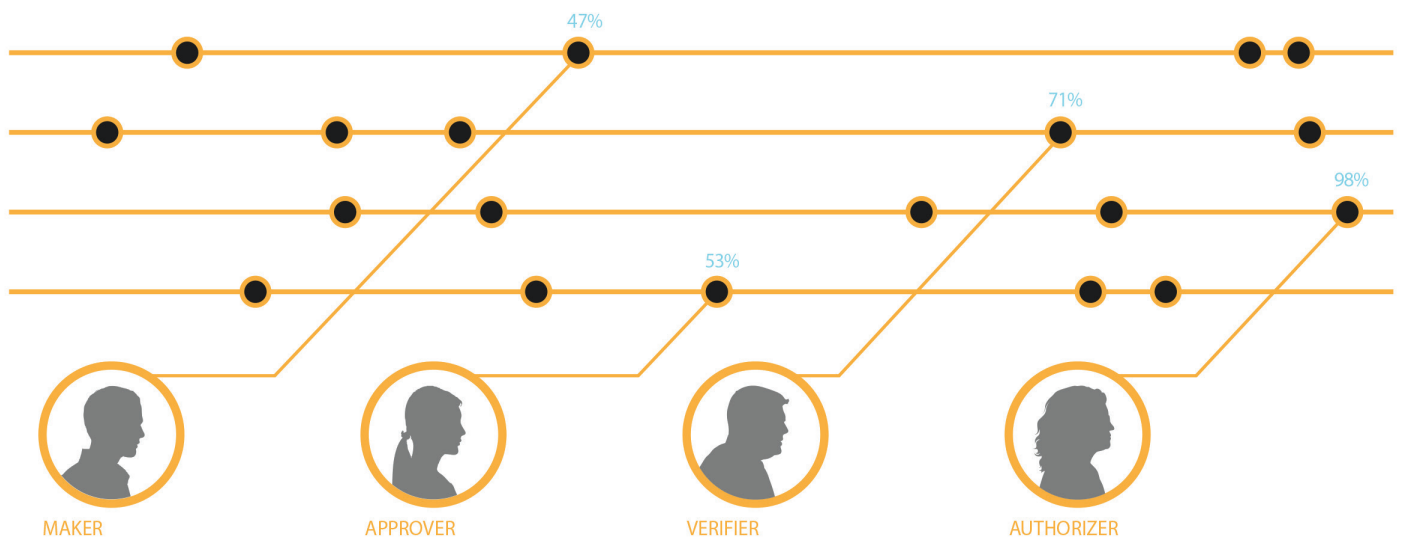


# SPACING LEARNING EVENTS OVER TIME *WHAT THE RESEARCH SAYS*



*“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 research<sup>1</sup> 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.

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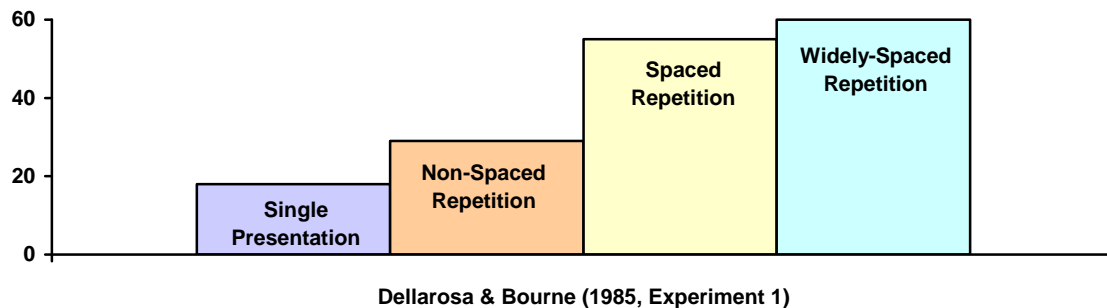
<sup>1</sup> One of the reasons the spacing effect is so often researched is that the phenomenon runs counter to our everyday understanding of how learning works. How can it be that exactly equal learning presentations—the first one using a widely spaced repetition and the second one using a narrowly 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.

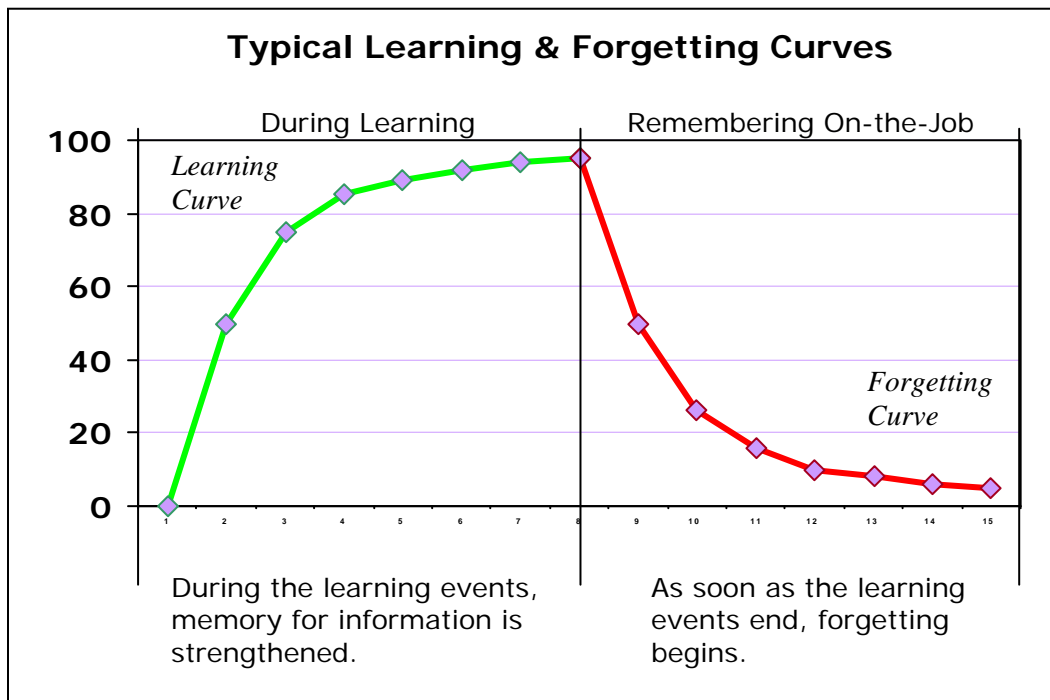
### *Side Effects of Spacing*

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.<sup>2</sup>

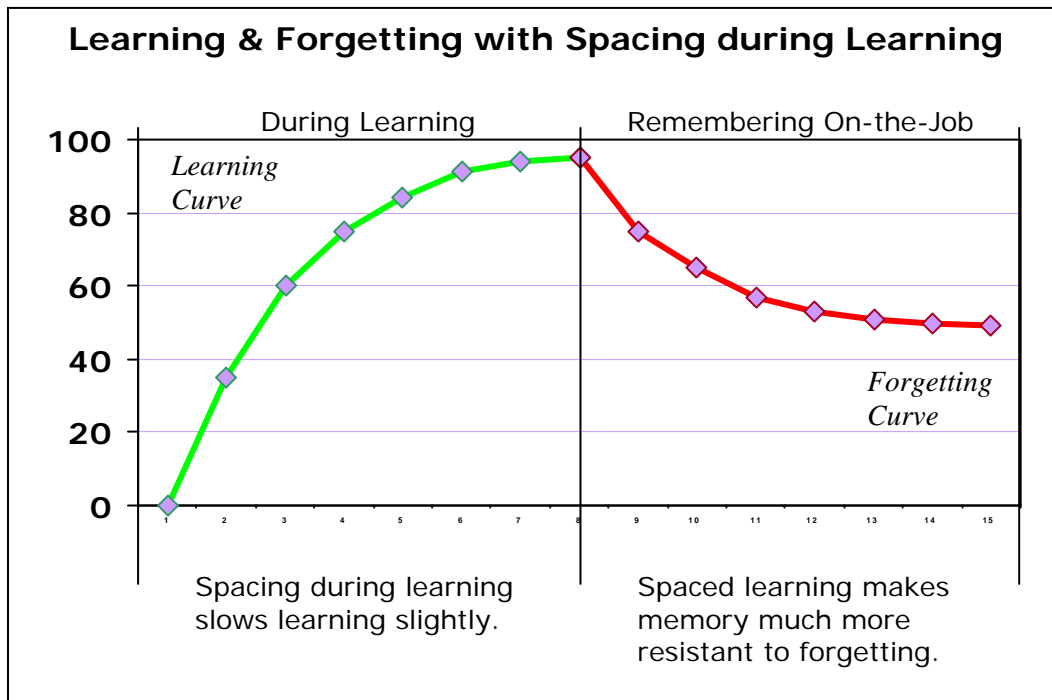


Notice that people tend to learn things relatively quickly, but that true expertise takes time and lots of learning effort. Note also that forgetting happens rather quickly in most situations.

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.

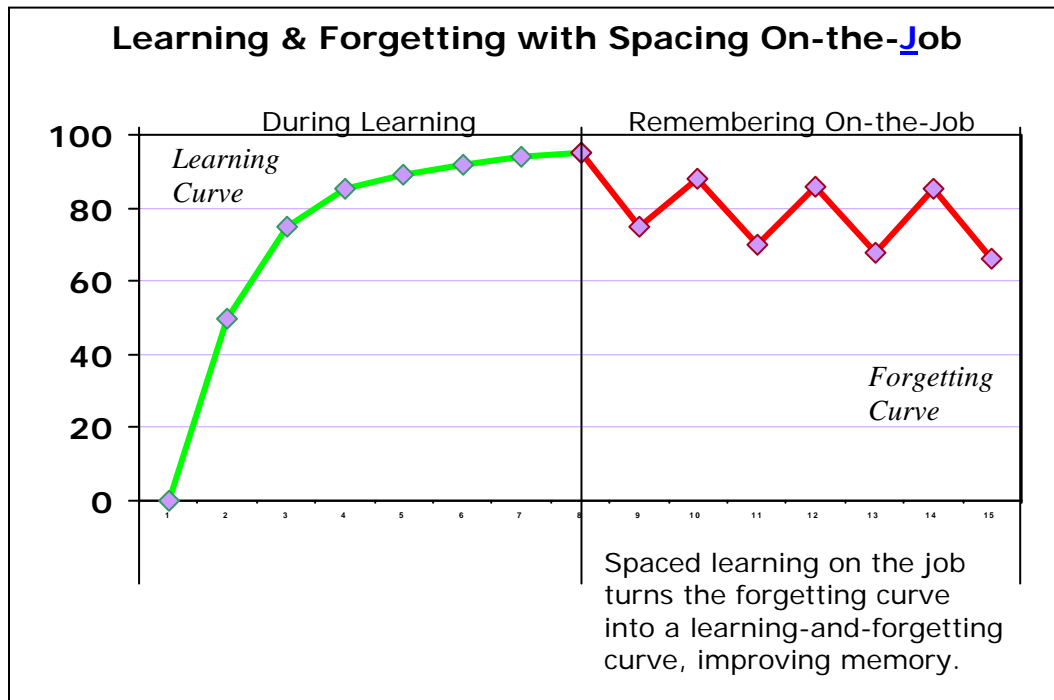
<sup>2</sup> Because all learning situations are unique, the curves displayed are only representative of the general concepts involved. Your learning results will vary.

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 work<sup>3</sup>.

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<sup>3</sup> 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.

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