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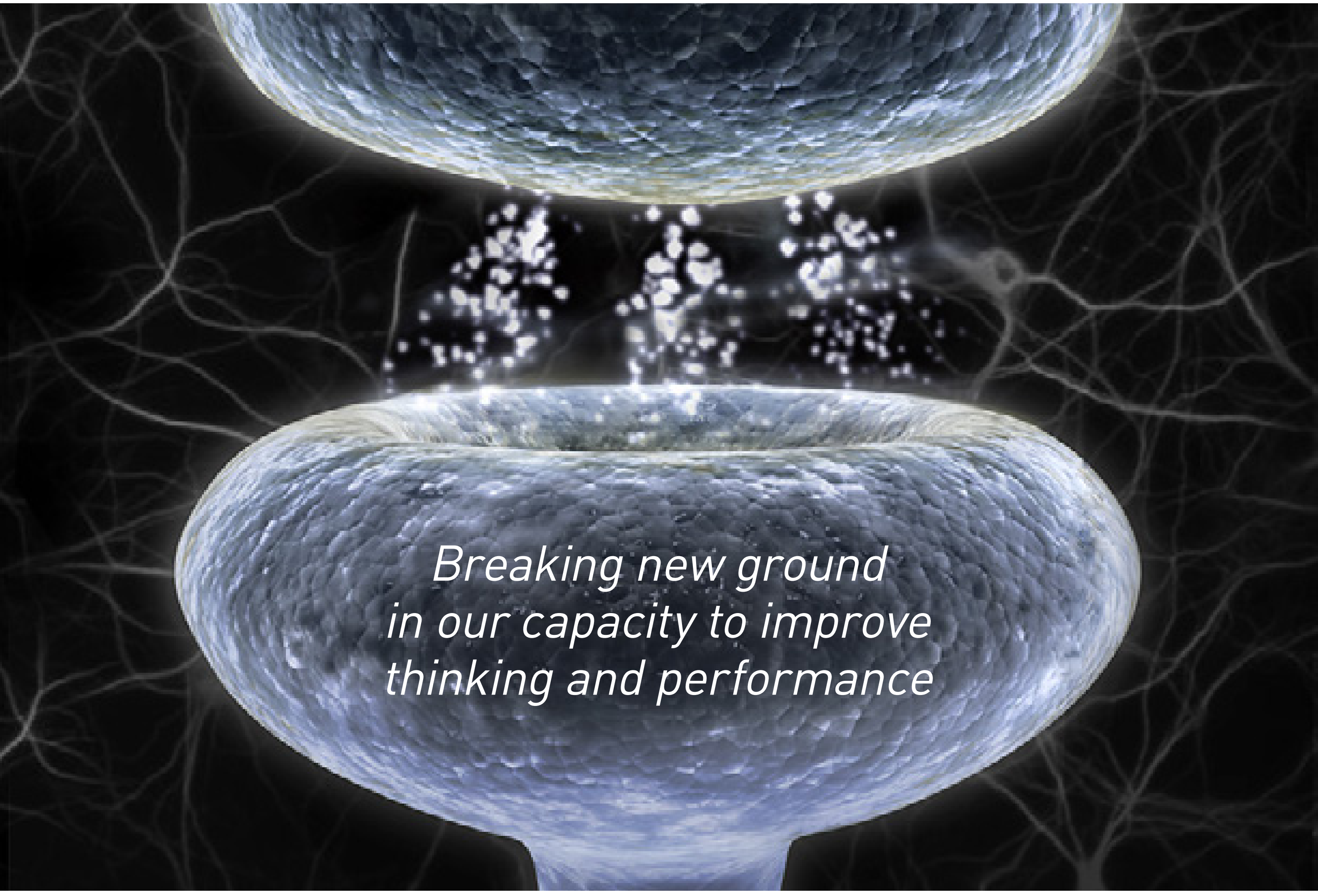
The Science of Making Learning Stick:
An Update to the AGES Model

Josh Davis, Maite Balda, David Rock, Paul McGinniss and Lila Davachi



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AUTHORS

Josh Davis The NeuroLeadership Institute
Corresponding author: joshdavis@neuroleadership.org

Maite Balda Columbia University, Department of Psychology

David Rock The NeuroLeadership Institute

Paul McGinniss The NeuroLeadership Institute

Lila Davachi New York University, Center for Neural Science and
New York University, Department of Psychology

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In the ever-changing world of modern business, one constant is the need to learn. With the rapid pace of change and the unpredictability of technologies and markets, there is no way to teach all that is necessary prior to entering the workforce. And continued learning once on the job, is a must. Being able to facilitate rapid learning at significant scale has become a central pillar of the new workplace. In 2010, Davachi et al. outlined four principles from the neuroscience of learning about how to make ideas stick: Attention, Generation, Emotion, and Spacing, which we called the 'AGES' model. Since then, a large body of learning and development practitioners around the globe have learned these basic principles as a foundation for understanding, improving, and reinventing approaches to developing and delivering learning. More recent studies are suggesting new ways to hone the AGES model. We report on the ways that these lessons from neuroscience can add to our toolkits for making learning stick. We suggest that if these principles are addressed, regardless of the other factors in a learning experience, that experience can be one that leads well to lasting learning.

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The Science of Making Learning Stick: An Update to the AGES Model

Josh Davis, Maite Balda, David Rock, Paul McGinniss and Lila Davachi

Only 42% of employers believe that their new hires were adequately educated and trained before coming to them (Mourshed, Farrell, & Barton, 2012). Taking educational matters into their own hands, organizations put roughly $164 billion into learning in 2012, with an average of $1,195 spent per employee, according to the 2013 American Society for Training and Development (ASTD) State of the Industry Report. Businesses also spend real money on learning and education programs each year because they recognize there is constantly new knowledge the people in their organizations need to master. There is also simply no way for new workers to be sufficiently educated ahead of employment, ahead of a new role or ahead of changing business circumstances. Also, scientific advances are made daily. What used to be fiction in many cases is now fact. For example, Modular Prosthetic Limbs allow amputees to have prosthetic arms that can be controlled by their minds (Collinger et al., 2012). The pace of technological change is so quick that entire product categories are appearing regularly, such as computing tablets and brain-training games. Even basic trade is changing as, for example, a common currency in parts of Africa is cell-phone minutes ("Airtime is money," 2013). And that is to say nothing of the need to learn about different cultures with whom we are able to connect with greater and greater ease. Attempting to apply old knowledge and expectations to these new contexts is a recipe for missed opportunity.

Despite acknowledgement of the importance of continued professional learning, as well as the substantial money and time invested by many organizations, all too often the way we learn is based on flawed models built around one big event. Information and skills from events that only cover concepts one time have been shown to yield little long-term retention, even when quality and satisfaction ratings for the learning event are high (D. S. Bell et al., 2008).

It is possible, however, to transform learning programs into events through which people do retain their knowledge and use it. Neuroscience suggests four principles that embed new learning so that it sticks (Davachi, Kiefer, Rock, & Rock, 2010). The four principles, which we term "AGES," summarize the big drivers of memory systems in the brain during encoding: there must be sufficient attention (A) on the new material; learners must generate (G) their own connections to knowledge that they already have; moderate levels of emotion (E) are necessary; and coming back to the information regularly—spacing (S)—works wonders. Since 2010, the AGES model has been introduced to a large number of learning professionals, including organizational learning experts, instructional designers, facilitators, trainers, and coaches. The framework has been presented at NeuroLeadership Summits and featured at several major learning conferences (e.g., ASTD, now called ATD) on multiple continents. Recently, we enriched the AGES model by reviewing the neuroscience and psychological literature on learning that has come out since the model was developed in 2010. We have discovered new lessons that we believe give both those facilitating learning and learners a substantial leg up when it comes to helping learning stick in our work lives. Based on feedback we have received on the original paper, we have also further enriched the model with a broader range of foundational insights, such as data on the limits of attention.

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Note also that despite the increasing demand for effective learning, the solution need not be ever-increasing learning budgets. We will argue that when the lessons from this paper are applied, learning programs can actually become less expensive while more effective. When the essential ingredients of learning are there, learning designers, trainers and facilitators can be more flexible with other aspects of their programs, like total time on task, co-location requirements, materials, and technology aids.

The essential ingredients of learning are those factors that create optimal conditions for one particular brain region, called the hippocampus, to do its job. The hippocampus runs along the innermost lip of the brain's cortex. It registers those experiences that are to be remembered when they occur, and then can later re-activate the relevant brain regions, in appropriate synchrony, across the whole cortex, facilitating recall of those memories. There are ways to leverage attention, generation, emotion, and spacing to help the hippocampus perform optimally. We address our most up-to-date understanding of this research below.

Attention

In 2010, Davachi and colleagues explained the mechanisms by which attention facilitates hippocampal memory encoding. Building on that work, we share here three facts about the relationship between attention and learning that are central to optimizing learning: 1) Attention has limits of only about 20 minutes before needing a refresher; 2) multitasking is the enemy of learning, and 3) attention is especially susceptible to interference with materials of the same modality (e.g., reading language and hearing language).

...multitasking is the enemy of learning...

Studies have long since demonstrated that we can only pay full attention at most for 20 minutes at a time (Hartley & Davies, 1986). Yet, this lesson needs to be re-taught regularly, as it goes against the impulse to provide people with lots of data in an efficient amount of time. The pressures of work these days lead many people to believe they are doing their audience a favor—or adding value—by condensing more information into a lengthy and uninterrupted learning block in which they ask the audience to keep focused for 30 minutes, an hour, three hours, or longer. While that might efficiently put the information in front of the learner, it actually decreases the chances the learner will absorb it. The brain will lose focus unless its attention is recaptured roughly every 20 minutes or less.

Most trainers have techniques for capturing or rejuvenating attention. But the frequency of employing them is generally too low, to everyone's detriment. This is not because education needs to be entertaining, but rather because recall is aided by focused attention on the subject to be recalled. A word on entertainment in learning is perhaps warranted. When it guides focus onto core content it is a plus. However, as many of us have experienced, or even been guilty of ourselves at some point, trainers may end up introducing entertaining distractions, like a game or interactive technology that obscures the content. Capturing attention in such a way as to focus onto key messages needs to be the aim.

What happens in the brain when we lose and then recapture attention? There are actually two separate systems of brain regions that play off of one another. One is driven by goals and intentions. It serves the function of directing our attention toward something we choose to focus on. This system is called the dorsal attention network, because it is spatially located relatively higher up in the cortex (higher is more "dorsal" in the language of directions in the brain). Then, there's a second system that grabs our attention away to focus on things coming into our senses from the external world. This system is called the ventral attention network (spatially located lower down, or more "ventral" in the cortex) (Corbetta, Patel, & Shulman, 2008). While it might be tempting at times to wish the ventral system could just be shut down, so we could stay focused once we get going on something, it would actually not work to our benefit. The two systems are more like ballroom dancers. One without the other doesn't really get the job of dancing done.

The reason for this dance is that things necessarily change, and we need the capacity to both spot when the world has changed and also to refresh each system so that our attention can refocus optimally. Imagine looking through binoculars set at one focal length at a bird in the trees. One focal length is fine if the bird never moves. But if it does, you'll want the ability to update the focus. Analogously, the ventral system grabs attention when something changes in the environment—especially when unexpected—making it possible for us to react more effectively. Meanwhile, the dorsal system gets a chance to refresh and update so that we can choose to refocus on the moving bird or search for another animal.

While the interplay between the dorsal and ventral systems helps explain why attention tends to shift around rather than staying put, a separate mechanism may also be at play. Whenever we put in effort at inhibiting our impulses,

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that effort tends to fatigue various executive functions (Baumeister, Bratslavsky, Muraven, & Tice, 1998). Suppose you are trying to stay focused on a lecturer at the front of the room who has been droning on for some time. It seems reasonable to suggest you would find yourself frequently inhibiting the urge to glance around the room, to check email on your phone, or attempting to tune out the distracting noise from construction outside. Perhaps you would find yourself politely attempting to inhibit the desire to move, or to interrupt and ask the lecturer to get to the point. You may even find yourself lost in thought about what happened the day before, when suddenly you are called upon in a pop quiz–like fashion and find yourself in need of inhibiting those memories of the day before and directing your cognitive effort to focus on the information you need to recall in order to answer well. These forms of inhibition are likely to rely to some degree on a single prefrontal brain region that has been dubbed "the brain's braking system" (Houghton, 1996; Kuhl, Kahn, Dudukovic, & Wagner, 2008; Lieberman, 2009). Continually putting the brakes on oneself—constantly exercising self-control—is likely to mentally wear you out (Baumeister et al., 1998).

The brain will lose focus unless its attention is recaptured roughly every 20 minutes or less.

What do the limits of attention mean for the trainer and learner? After 15–20 minutes of sustained attention, a trainer can either provide downtime to let people mentally refresh, or introduce something novel or unexpected, such as a chance for learners to focus inward, be active, ask questions, change learning format, discuss, and so on. If the learner understands this principle and is in a situation where he or she must focus during a long class without a break, he or she can apply this principle internally. How many times have you sat through a training and wondered, "When will this get interesting?" while fighting to stay focused? In those moments, there might be an alternative action to take—one possibility is to deliberately tune out for a minute to re-charge and then consider what's novel in the material, or try to look at the material from a whole new context.

While we've discussed the limits of attention above, we have not explicitly talked about why that matters for memory. After all, perhaps we can learn simply by being exposed to information—picking it up in the background. It turns out not to be so when talking about conscious recall. It may be true to some extent for picking up patterns of behavior and non-conscious social mimicry (van Baaren, Janssen, Chartrand, & Dijksterhuis, 2009); however, for conscious recall—the kind of learning we often want from training programs—a single focus of attention is important.

The literature on the deleterious effects of multitasking helps reveal how critical a single focus of attention is when we want to optimally activate the hippocampus to signal that a new consciously recallable memory should be formed.

Although its name refers to doing more than one task at a time, neuroscience illustrates that what is actually taking place in our brain during multitasking is a rapid switching between two actions. Thus, if we multitask while learning, our attention will be divided in parallel tasks that we alternate between, and the attention loss due to that divided attention negatively affects our retrieval success (Gherri & Eimer, 2011). Participants in the studies by Gherri and Eimer (2011) had to search for a visual target and at the same time try to learn a narrated text passage. Meanwhile, the experimenters recorded their brainwaves. The first result was unsurprising: The participants did worse at the visual task when they had the listening task at the same time. The second finding was quite revealing. The brainwave results showed that participants engaged different brain regions depending on the task they were doing, and that participants were unable to activate both regions at the same time. Therefore, rather than effectively splitting their focus, it seemed they were rapidly alternating focus between the two tasks. The delays and performance decrements apparently came from the recurrent need to refocus attention on each task.

Now let's take a look at what's happening in learning environments. At the most well-funded, "cutting edge" end of the spectrum, there are business school classrooms that are fully networked, enabling every seat to have high-speed internet, laptop power, and other fun media gadget hook-ups. More and more interactivity is being brought into learning, with social media platforms finding their way into the minute-to-minute learning experience. At younger ages, some school systems are spending huge sums of money—£400 per student in a UK state school for laptops, and $1 billion in Los Angeles, much of it for individual iPads in the classrooms, including in elementary schools (Blume, August 27 2013; Salkeld, March 30 2010). There is also a move to shift learning to iPads and similar technology, with some schools planning to eliminate physical books entirely over time in favor of digital media (Costa, 23 March 2012).

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Multitasking on a laptop during a lecture—a scenario also quite directly related to the typical training environment—has been shown to lower scores on an immediate test after the lecture, compared to those who do not multitask (Sana, Weston, & Cepeda, 2013). Moreover, people who are in direct view of a multitasking peer will score lower on a test compared to those who are not (Sana et al., 2013). We believe it is safe to say that multitasking is an enemy of learning. Consider what that means in the context of all the new computer-based distractions.

With such a strong opinion as this, you might wonder whether we believe there is ever a time when having more than one focus of attention in the learning environment is useful. The answer lies in using distinct sensory processing modalities. Imagine the common scenario in which there is a busy slide to read at the front of the room and the lecturer is speaking at the same time. Both require language processing, so it is impossible to focus on both at once. The learner is pulled in two directions and must either work to inhibit one totally, or must switch frequently to try to follow both at once. If, on the other hand, the slide shows a visual image that is a nice metaphor or reminder for what the speaker is talking about, then the learner need not divide attention as much. Language and vision centers in the brain are separate, so the visual and auditory can be part of a simultaneous experience, and when that is the case, the need to shift focus between the visual and spoken input is then also diminished. When trying to do various simultaneous tasks with different modalities, such as vision and manual operations, our cognitive resources can operate in parallel, though only for certain pairs of activities (Wickens, 2002). For example, it seems that auditory processing is easily disrupted by mental effort (Lang, Potter, & Bolls, 1999). Trying to do a second task—e.g., multitasking—requires mental effort. Visual processing is not as poorly affected. Perhaps this is because visual tasks can often be less effortful (Lang et al., 1999). However, research has shown that some loss of attention, and thus of memory, can occur even when the modalities are distinct (e.g. Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Gherri & Eimer, 2011; Naveh-Benjamin, Craik, Guez, & Dori, 1998).

Now, the most painful lesson about multitasking—those who think they are good at multitasking have been shown to be the worst at it. Although many people believe that attention constraints do not apply to them, ironically, people who report multitasking more often actually multitask worse than those who report multitasking less often (Ophir, Nass, & Wagner, 2009). Sadly, multitasking is an area where practice actually does not make perfect. Quite the opposite is true, in fact. It seems that those people who spend more time multitasking across various media (e.g., computers, tablets, phones, etc. at the same time) train their brains to have a harder time focusing and remembering (Ophir et al., 2009). Moreover, we may be completely wrong in our beliefs about our abilities to multitask. In one study, people who multitasked not only obtained poorer results, but assessed themselves as having performed better than when only carrying out one task (Wang et al., 2012). Even though multitasking (e.g. with reading, texting, typing, listening, and speaking at the same time) may feel optimal in terms of time and efficiency, facts illustrate this is just a misperception rather than an advantage.

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Some people might like to believe the findings from research on multitasking do not apply to them. Researchers have looked for so-called "super-taskers." Only 2.5% of participants in one study of people driving a simulated motor vehicle while executing a demanding auditory memory task were found to be able to do both without suffering in their performance (Watson & Strayer, 2010). However, these people were all in the top quartile of performance on those tasks. They thus may have been able to do one or both without a need for much conscious, focused attention. Perhaps a more difficult task for them would have yielded different results. So, even in the rare cases where multitasking is not a detriment, this applies to a tiny percentage of people, and we suggest it may pertain to just easy tasks or tasks that a person has done so repetitively that the task requires little attention or cognitive effort.

Understanding what motivates a person to multitask may help you end the practice. We suggest that the drive to multitask is twofold. One driver is the desire to try anything that will make us more efficient. The second is the misguided allure of technology. Technology is fun and a great way to pass time. It is probably safe to say that internet/phone-enabled technology is the new national pastime—sorry, baseball. It is not hard to suggest

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reasons why it is rewarding—it's fun, often provides novel experiences, offers hope of social connection, and provides for that well-rehearsed form of emotion regulation called distraction. And technology offers wonderful avenues for a learning solution to brand itself as current. But don't confuse excitement for benefit. Without strict controls so that technology is used to guide a single focus of awareness, its use probably hurts the capacity to recall learned material more often than not. Even when multitaskers have learned to achieve the same level of outcome as single-focus research participants, they needed more time to make up for their learning losses due to task switching (Bowman, Levine, Waite, & Gendron, 2010).

Implementation principles

To make best use of attention for learning that lasts, aim for a single focus of attention on the point to be remembered. Be thorough and consistent about limiting multitasking. If you do choose to divide attention at times, do so in separate modalities—e.g., a simple visual metaphor that serves as a reminder for what was said verbally. Recognize that attention will probably fatigue and drift roughly every 15 to 20 minutes, so allow it to—e.g., shift to discussion, digestion, or a break.

Generation

Generation is the act of creating (and sharing) your own connections to new or presented ideas. Importantly, it is the act of generation that matters and not whether the connections that are made are brilliant. When we take the time and effort to generate knowledge and find an answer rather than just reading it, our memory retention is increased. A practical example of knowledge generation at work is shown in a study by Kornell et al. (2009) where they demonstrated that using eight seconds to generate a response that turns out to be wrong (i.e., knowledge generation) followed by five seconds of studying the correct response (i.e., traditional learning) produces better recall than merely studying the correct response for the full 13 seconds. Since that time, other researchers have replicated these findings and taken them farther by showing that a number of factors can modulate the effect. These would be things like how related the meaning of the response was to a right answer, whether the person responding got feedback to help them correct themselves, and when the feedback was given (Grimaldi & Karpicke, 2012; Hays, Kornell, & Bjork, 2012; Huelser & Metcalfe, 2012; Knight, Ball, Brewer, DeWitt, & Marsh, 2012; Kornell et al., 2009; Vaughn & Rawson, 2012). So, not just any wrong answer will do, but a good-faith wrong answer that's on the right track coupled with some relevant and timely feedback seem to be the way to go.

The concept of generation, and several ways of doing it, were discussed in the original AGES paper by Davachi et al. (2010). Here, we go beyond that discussion to review what research is suggesting about a few types of generation that may be especially valuable. First, we'll discuss evidence regarding a special memory network for social information, and thus how linking to that memory network may be beneficial in the process of generation. Next, we'll take a look at the ways that metacognitive (thinking about your thinking) strategies are helpful. Finally, we'll review how the experience of "insight"—as it relates to new connections between information and ideas—can provide a nice boost to information retention.

Social information generation

Peer learning, group work, storytelling—all are common in learning environments. But the full benefit may not have yet been tapped. One thing these all have in common is that they involve thinking about yourself in the context of the broader social environment. Connecting to-be-learned information with the self and/or others is one way to create a rich network of associations that enhance activity in brain areas involved in memory, which has been shown to help with recall. In addition, there may be a special network for social memories apart from other memory structures. Thus, social information should enhance our opportunities for making new connections in ways that go beyond what other forms of generation might be capable of (Lieberman, 2012; Skuse & Gallager, 2009).

...distinct memory networks are involved when we aim to teach compared to when we aim to just study or passively learn something.

Humans are social animals, and hence, wired to thrive in community. Thus, person knowledge represents a rich, accessible network of information on which we can build when we are learning new information. The brain networks activated in social interaction will then be more likely to be linked to the new content. These networks include, for example, the medial prefrontal cortex (MPFC),

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a region important for processing identity, self-evaluation, and self-relevance (Heatherton, 2011). This is a brain region that would not necessarily be involved in forming new memories about technical skills, protocols, or data to understand, which might form the basis of a typical training program. Thus, connecting these kind of ideas to social thoughts or interactions provides an opportunity to generate richer connections to new ideas than might not otherwise occur.

For example, suppose training involves new safety protocols. One approach toward making that content social is for the learner to imagine its relevance in a social context. To do this, the learner might consider a situation in which a colleague, knowingly or not, cuts a corner in terms of safety, and how the learner will then support that colleague towards better safety. In thinking this through, that learner will be activating the social circuits in the brain and generating his or her own connections between the new content and that social processing.

One particularly useful way to leverage social processing capacity for learning may be for learners to take the position of teacher. Consider the well-worn phrase, "If you want to really learn something, teach it." It's easy to laugh knowingly at this sentiment, and sigh, as if to say, "If only..." After all, there can only be one teacher in the room, right? However, it seems that teaching one-on-one, dividing into small groups and taking turns being "teachers" with other learners in a learning environment, or even mentally preparing to teach vs. just trying to learn material, is enough to leverage this powerful phenomenon (Allen & Feldman, 1973; Bargh & Schul, 1980; Benware & Deci, 1984; Rohrbeck, Ginsburg-Block, Fantuzzo, & Miller, 2003). Teaching an idea is such a surefire way for deep learning that we would be remiss not to take advantage of it whenever we can.

At first, we might think that the reason that having each learner teach in some way could be beneficial is that a person who is to teach something will be motivated enough to study it more deeply—although in the same ways—than they otherwise would. It's possible that this mechanism plays a role. However, that doesn't seem to explain the brain data entirely. Lieberman (2012) argues that distinct memory networks are involved when we aim to teach compared to when we aim to just study or passively learn something. It turns out that when social information is part of the memory, activity in distinct parts of the brain are more predictive of how well the memory is embedded than is activity in the traditional memory centers that are key for recall of non-social information (Mitchell, Macrae, & Banaji, 2004). To help clarify, some examples of non-social information would be new protocols, new industry challenges to respond to, or interesting data points about marketing and sales to keep track of. Whereas examples of social information would be thinking about how protocols affect your social interactions, thinking about how your team can respond to new industry challenges, or thinking about how to message interesting new data points to key stakeholders who need to hear them.

Perhaps one of the most pleasant consequences of leveraging the value of social generation is that it tends to make teaching or learning easier and more enjoyable—quite the opposite of the hard work we often expect when making changes in the ways we work. And it need not be complex. For example, one author of this paper (JD) routinely asks his classes what ideas from the day they would like to share with someone else, with whom, and when? It can't be answered without linking the content to social processing.

Metacognitive generation

Metacognition means thinking about thinking. Learning benefits greatly when metacognitive skills are well developed (Schwartz, Scott, & Holzberger, 2013). There are many ways to think metacognitively. We'll discuss two that seem to be especially helpful: 1) It is possible to be aware of what you know and don't know, and 2) it is possible to think about how some new information is relevant to who you are as a person.

One well-known method to improve awareness of what you know and don't know is self-evaluation. Giving yourself a test enhances learning, compared with studying without evaluations (Roediger & Butler, 2011). Specifically, receiving feedback after getting the answer wrong on a test—after memory failure—leads to better retention than studying the correct answer for the same amount of time overall (Hays et al., 2012). Effects of re-study of this magnitude have been shown to persist four months later—e.g., 33% versus 57–60% after two versus four to five relearning sessions (Rawson & Dunlosky, 2011). Self-testing promotes learning as well by reinforcing the links established with generation. Every time a person retrieves knowledge, the link between a cue and that knowledge is enhanced (Karpicke & Blunt, 2011).

A second form of metacognition that benefits generation is to connect input with ideas about ourselves. This is similar to the idea of social generation we discussed above, but we separate it here to specifically highlight the value of connecting ideas to thoughts about oneself, even if that is outside of a social context. For example, suppose there is content to be learned about a new set of business constraints. If a learner asks himself, "How will knowing this content relate to who I see myself as?" that should create links between the new content and a robust existing neural system. That hypothesis seems to be consistent with research findings. Kim and Johnson (2012) used fMRI

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to explore activation in a brain region called the medial prefrontal cortex (MPFC), which is recruited in explicit self-referential processing, as it might relate to memory. The researchers had their participants rate how much they liked images they were shown. Later, those images were randomly assigned as belonging to the participant or to another person. There were memory advantages for those objects that had been assigned as belonging to the participants themselves. Sure enough, activity in the MPFC was associated with superior subsequent memory for objects assigned to the self.

Insight generation

Insight, that eureka moment when the unconscious mind solves a problem, is perhaps the most valuable form of generation. We've all had insightful moments—walking in the woods, talking to a friend, drifting off to sleep—when, all of a sudden, a solution comes. Insights are the result of wide-scale reorganization of the elements of a problem into a new and previously non-obvious solution. Insight is directly related to generation by connecting ideas in a way they have not been previously connected. Thus, insights are, by definition, self-generated connections to existing knowledge structures. And, as anyone who has had an insight can attest, they are energizing and engage us with the new ideas that are learned. This may be an important part of the reason insights are memorable. Even though "Aha!" moments are a one-time event, their result is often well-preserved in memory. "Aha!" moments activate the amygdala—a part of the brain reactive to emotionally arousing stimuli—which promotes long-term retention (Ludmer, Dudai, & Rubin, 2011). So, the emotional charge of an insight seems to be an important part of the mechanism by which those memories stick.

Insight, that eureka moment when the unconscious mind solves a problem, is perhaps the most valuable form of generation.

"All well and good," you might think, "let's hope for some insights." It turns out insight is not just something we need to hope for. There is a fairly reliable process leading to an insight and it is possible to guide a person through that process. Jung-Beeman, Collier, and Kounios (2008) and Rock (2011) go into depth about this process. In short, start with awareness of an impasse—for learning, there is always the impasse of how a lesson will be relevant for the learner. Then explore, metacognitively, how the learner has been thinking and what solutions they are already considering. Finally, allow quiet time for internal reflection on the weaker, less-frequently used neural signals that have been triggered.

Implementation principles

If you want learners to learn, offer ways for them to generate their own connections between new ideas and their existing knowledge. Helping them self-generate connections will be more valuable than telling them the connections. Generation pairs well with attention constraints, as it offers learners something to turn to after 15 to 20 minutes of receiving content, thus magnifying the impact of the time spent.

In particular, give learners questions and tasks that guide them to consider social processing and metacognition around the new content. Specifically set up the conditions for insight. When you break for generation, create the space and time for quiet, internal reflection that is not directly on a specific problem. Rather, encourage learners to reflect on their thought process surrounding a solution—e.g., ask the question, "How many ideas are you considering about how you might apply X?" Then create the space for reflection.

Taking Stock of the Lessons So Far

An example of how these lessons about learning might play out could help before we introduce the next piece. Imagine you've been flown in from out of town, arriving at 9:00 a.m. for a day of learning, where you're met with a laptop connection at each desk, Wi-Fi in the room, all desks facing forward, and dim but attractive lighting, so as to see the slide projections while maintaining some visibility. A speaker begins talking in front of beautiful, professional-looking slides, each one with graphs, tables, references, and paragraphs of useful text, not to mention logos and branding elements. On your laptop, you have an electronic copy of the slides and a series of paper handouts. The speaker courteously offers to plow ahead, rather than take breaks, so as to respect your time and deliver maximal content to you. Not hard to imagine, is it? You were probably at such a learning event within the past few months. On the surface, this sounds like a well-thought out plan, incorporating technology and honoring the needs of busy, important executives. But, every aspect we've just mentioned probably hurts learning more than it helps.

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Now, you are becoming equipped with the scientific grounding to understand why this modern ideal is contributing to non-optimal learning. So far, we've seen reasons why this is a terrible platform for adaptive use of attention and interferes with many opportunities for generation. Driving through from 9-to-5 with minimal breaks should make sustained, focused attention extremely difficult. While there is probably some benefit to the social relationship in offering learners a choice to plow through vs. break, there is a stigma against wanting breaks, so it's a good way to ensure necessary brain breaks get missed. The laptop and Wi-Fi encourage multitasking and interfere with a single focus of attention. The forward-facing desks and dim lighting hinder breaking for directed social interaction that is so useful for generation. And the beautiful data-packed slides divide attention between the speaker and the slides. There are other errors as well, and we'll turn to those now.

Emotions

It turns out levels of emotional arousal matter for making learning last, and positivity is better than negativity if you can generate it. As summarized by Davachi et al. (2010) with emotional arousal, the hippocampus—the part of the brain that reactivates neural circuits until a new memory is embedded—gets additional signals from brain regions that respond to arousing stimuli. This helps activate the hippocampus to the point where it can do its job more effectively, just like putting a car in a higher gear can make it easier to drive at high speeds. However, too much emotional arousal can trigger a meltdown of sorts, indirectly reducing the performance of the hippocampus. It can interfere with attention, which can then interfere with memory. As we all know from experience, strong emotions can be distracting, and without focus, it is harder to learn. It's not hard to go too far when dealing with negative emotions, because human brains are designed to detect threats quickly and respond strongly to them. Positive emotion has more leeway in that regard, and also has been shown in research to aid creativity, insight, and to expand perception—all of which are helpful in a learning context (Davachi et al., 2010).

Now consider the executive flown in for the 9-to-5 learning event. If multitasking is encouraged, the first emotion likely attendant is anxiety while seeing the emails come in, and being unable to really address them. Chances are many executives in this situation would also feel a mix of fatigue and irritation at being pulled in so many directions. That would be negative emotion—less preferred than positive—and thus is more likely to over-arouse our executive. Also, this kind of emotion drives attention away from the content to be learned. Far better is to help free the learner of emotional distractions and to encourage the kind of positive emotional charge that comes from things like insight and meaningfully engaging with peers.

Complementing the findings discussed in Davachi et al. (2010), evidence also suggests that not only does the level of emotional arousal matter, the act of regulating one's emotions can influence learning. Learners can be taught to take emotional matters into their own hands, to aid the learning journey. In the example of the compulsory 9-to-5 learning environment that our executive has flown in for, there is ample opportunity for emotion regulation. For instance, the method of "labeling an emotion" has been shown to clear away low level emotional distractions to allow for conscious focus (Lieberman, 2009; Lieberman, Inagki, Tabibnia, & Crockett, 2011). We can imagine, without much difficulty, our executive becoming irritated and even insulted as he or she perceives the injustice of being forced to spend his or her time at a dull learning event. Simply labeling the experience as "feeling angry," without thinking more about it or diving into why he or she feels that way, could reduce negative affect (Lieberman et al., 2011).

...the act of regulating one's emotions can influence learning. Learners can be taught to take emotional matters into their own hands, to aid the learning journey.

A second form of emotion regulation has also proven valuable in this arena, a method of emotion regulation called reappraisal—changing one's initial interpretation of a stimulus or situation. The regular use of a reappraisal strategy correlates with academic performance by helping maintain focus (Leroy, Gregorie, Magen, Gross, & Mikolajzak, 2012). In a study design that mimics real life in a number of applicable ways, the researchers tested participants' ability to ignore tempting activities, such as looking at interesting posters and pictures on the wall, while studying relatively boring material. Compared to

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controls, those who reappraised (by framing the task as an opportunity to improve their memory) were less distracted, kept a higher level of enthusiasm towards completing their assigned studies, and showed better overall task performance.

The above examples describe how emotion regulation can help a person stay focused, rather than be distracted by emotionally charged input. However, emotion regulation also may have a more direct effect on memory. In one study, participants observed negative images and were asked to regulate their emotions with reappraisal, rethinking the meaning of the image in a way that it was less negative, e.g., that it wasn't real but just a scene from TV (Hayes et al., 2010). In the brain, the amygdala, the hippocampus, and the left inferior frontal gyrus—a region associated with language and cognitive control—worked together to help memory. When those regions were simultaneously activated during reappraisal, the stimuli were better remembered, and memory was enhanced significantly when reappraisal was used compared to the control conditions.

Implementation principles

Moderate levels of emotional arousal when learning enhance memory retention. This emotion can be positive or negative and still provide benefit. But, there are secondary benefits to positive emotion—it is harder to over-arouse with positive than it is with negative emotion, and positive emotions can facilitate other factors helpful for learning, such as insight and social collaboration.

Spacing

Spacing—having some space (usually a day or more) between learning and review sessions—is the most counterintuitive and yet perhaps most important of the four learning principles. People tend to believe it will work less well than cramming the learning into one marathon session, as we might have done in school before an exam (McCabe, 2011). This belief is so ingrained that even when we perform better after spacing, we can be unaware of it. One study found that 90% of participants had better performance after spacing than cramming. However, 72% of the participants reported that cramming was more effective than spacing (Kornell, 2009).

Misperceptions about the value of cramming for a test vs. distributing one's learning probably stem from the experience that most of us have had—that we've gotten away with it for a test in school. Or at least we think we have—cramming is actually associated with low achievement (Hartwig & Dunlosky, 2012). However, high achievers are guilty of it too from time to time. Within a few days of study, we do tend to have much better recall than we do a month or year down the line (Carpenter, Cepeda, Rohrer, Kang, & Pashler, 2012), so cramming can be effective if the aim is to take a test (i.e., short-term). But, as we'll see, it is not so effective if the aim is lasting learning. Sadly, performance on an exam, not learning, is what is rewarded in many school settings. As noted in the generation section, self-evaluation can be useful when it's a tool for people to identify for themselves what they need to study, but when the test is the end goal, it's a different story. When there is no test, and only a need to have actually learned something —as is more common in the workplace—spacing out the learning sessions is the far better choice. Davachi et al. (2010) described the behavioral phenomena and neuroscientific value of spacing. Here, we offer more direction about how to put it into practice.

Sleep not only helps to strengthen memories, but also to actively forget irrelevant information, thus optimizing memory for what is relevant.

Are there minimal spacing gaps? There are some useful guidelines. First, consider spacing within a single study session. In that context, the space of just a few minutes (with a filler task between study sessions) has led to significantly better recall of passages participants read than passages read all at once. These effects were also shown to be long-lasting and persisted for at least a week (Karpicke & Roediger, 2010).

When we look at building in spacing between study sessions, rather than within a study session, the rule seems to be that an ideal minimal gap is one that includes sleep. Even within the same day, having the time for sleep makes a difference. A 12-hour spacing gap during the day (with no sleep) is helpful, but less good than 12 hours overnight, and sleep is especially relevant for more challenging material (M. Bell, Kawadri, Simone, & Wiseheart, 2013; Jessica D. Payne et al., 2012).

Perhaps the most profound benefit of spacing is that it allows for sleep. While we can learn without sleep

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between learning sessions, for long-term retention, sleep does wonders, and it requires no cost, effort, or additional total time devoted to learning sessions. Sleeping provides optimal conditions for processes that integrate newly encoded memories into long-term storage. Memories are reactivated during sleep when new memories that would be prone to decay are transformed into stable memories that are preserved long-term (van Dongen et al., 2012). Sleep not only helps to strengthen memories, but also to actively forget irrelevant information, thus optimizing memory for what is relevant (Bennion, Mickley Steinmetz, Kensinger, & Payne, 2013; Payne, Chambers, & Kensinger, 2012; Saletin & Walker, 2012). It has been suggested that both slow-wave sleep, which comes in the first half of the night, and rapid-eye-movement (REM) sleep, which comes more at the end of a full night of sleep, play an active role in learning by integrating newly encoded memories with pre-existing knowledge (Born & Wilhelm, 2012; Diekelmann & Born, 2010; Rasch & Born, 2013). For the vast majority of people, a full night of sleep is around eight hours (Rock, Seigel, Poelmans, & Payne, 2012)—give yourself enough sleep to get those REM cycles.

So far, we've addressed whether there are minimal spacing gaps that make sense to aim for, but there is also information as to what is optimal when working with more time. The optimal spacing gap turns out to be a function of how long the information is needed. In a research context, there is always a test at some point, to determine how much has been retained. For peak performance on the test, the optimal spacing appears to be roughly a third or less of the time until the test. A review of the spacing literature found that for a final test seven days after the last study session, the best retention came from a spacing gap of one day; for a test 35 days later, the optimal spacing gap was 11 days; for a test 70 days later, the optimal spacing gap was 21 days (Cepeda, Vul, Rohrer, Wixted, & Pashler, 2008). The authors suggested 10–20% of the test delay would be a good bet.

However, many readers will recognize that in the context of the workplace, learning is seldom done with a single test date in mind. Rather, it is meant to be continually accessible in memory, both in the short term and long. Thus, we suggest spacing one time on the order of days, once on the order of weeks, and once on the order of months to promote optimal retention and recall.

Indeed, research indicates that revisiting the information three times is ideal in terms of maximal benefit before diminishing returns for additional study sessions kick in (Rawson & Dunlosky, 2011). Moreover, these findings pertain to data about the kinds of conceptual learning that match well to some of the kinds of learning going on in the workplace. In that research, the information to be remembered was an understanding of new concepts. Revisiting the information just once, after a few days, brought memory up to about 40% on a test a month and half later. However, revisiting the information three times, with a handful of days between each session, brought memory on that test up to about 55 or 60%. Adding additional learning sessions helped, but not enough to warrant the additional effort.

Complex expertise-related knowledge has also been shown to benefit from spacing. A study on college math learning (the topic of permutations) showed the benefit of splitting study time across two sessions—one week apart—versus doing the same amount of studying all at once (Rohrer & Taylor, 2006). When tested a week after studying was complete, both groups scored in the 70s in terms of percent. But four weeks later, the spaced study group had essentially retained their knowledge, at 64%, while the group who studied all at once scored half that.

One final note on spacing is that despite its clear and uncontroversial benefit, people who are not educated on the topic tend to believe it is less important than other learning strategies. Although spacing (in this case, retrieval practice all within one session) outperformed another tried-and-true memory method—concept mapping—by roughly 15%, participants in that study thought that they had learned more in the concept-mapping condition (Karpicke & Blunt, 2011).

...memories are not like documents we keep in computers or file boxes. We don't simply make them once and store them. Instead, we grow our memories... This takes time.

In summary, time between initial and subsequent learning is critical. This is because memories are not like documents we keep in computers or file boxes. We don't simply make them once and store them. Instead, we grow

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our memories. For humans to learn, neural connections have to change. This takes time. Once some neural changes have occurred, we can go back and embed the learning by practicing the use of our new neural connections, which strengthens their interconnectivity.

Implementation principles

Appealing to intuition alone is not sufficient to convince people of the value of spacing. Educate and inform them with the science behind spacing. Plan to space out learning so that content is revisited in some engaging way, especially with some sleep in between study sessions, and seek to have people return to the material once on the order of days, once on the order of weeks, and once on the order of months, if possible.

> *...the very social nature of the human brain means that making learning social brings potential for magnifying the effects of each of the other aspects of AGES.*

Multiply the Power of Social Learning

We discussed in the generation section the potential for memory to be enhanced when we link information to social cognition. However, the very social nature of the human brain means that making learning social brings potential for magnifying the effects of each of the other aspects of AGES. Imagine that in our prior example of the executive attending the full-day event, he or she was asked at some point to identify a key business partner who could benefit from one of his or her insights from the day, then tasked with actually teaching or sharing that message in a useful way with the business partner at a later time. That social interaction in which the teaching or sharing occurs is one that is well-suited for focusing attention on the critical material. No one wants to look the fool, and on the flip side, there's a social benefit to being interesting or adding value through the conversation. Generation is enhanced in the ways discussed earlier, the moment of connecting the material with thoughts about what is really essential to the content, and how the other person will receive the information. Thus, the self-generated network of linked information must expand. In the area of emotion, anyone who has been pleased with acknowledgment or upset by rejection can attest that social interactions are frequently emotionally arousing in both positive and negative ways. This type of interaction seems likely to have emotional charge as the potential for appreciation or annoyance is real. That emotionality—highly connected to the strength and value of the message and what it means for the relationship—ought to enhance the emotional influence on memory. Finally, the spacing is built in. Simply by teaching or sharing at a different time, spacing has occurred.

A move toward leveraging the power of social processing can be as simple as a subtle shift in the way one closes a session. Where we may have ended by asking people to state what they learned, we can instead ask them who they will share a lesson with, or how they will use the lesson with another person.

Conclusion

Learning is now central to being competitive in business, and businesses—aware of this need—are trying to provide valuable learning opportunities. Yet, so many times, employees return to work only to forget and discard the new information. There is considerable research regarding how to most effectively make learning stick. Davachi et al. examined the evidence in 2010 and pointed toward four principles about how to prepare the brain to be ready to embed new learning. Here, we extend that model by summarizing the lessons from research into effective ways to take advantage of those principles.

In summary, to get the most out of learning sessions, start by paying attention to attention. Change focus every 20 minutes or so and allow focus circuits to refresh. Remove multitasking wherever you find it. Multitasking will take a toll. Once your learners have given a single focus of attention to an idea, move to the next step, which is to guide them to self-generate connections to their existing knowledge. We have discussed research here pointing to three ways to do this well—link new ideas to social information, link to meta-cognitive understanding of their own processes and knowledge gaps, and leverage the power of insight to rapidly embed new learning. In the realm of emotion, both learners and trainers can become aware of their emotions, and regulate them to achieve optimal—moderate-positive—emotional arousal for learning. Finally, in the domain of spacing, we see that one-time learning misses out on an important learning tool—

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returning to your material after some time has passed is key. And, where possible, allow for sleep in between. Sleeping gives a brain the ideal conditions to much more thoroughly encode what has been learned.

A challenge to the reader

We now challenge you to let go of other constraints based on how you may have conducted or engaged in learning in the past. Here's one example of a re-do of the story we told before, about the busy executive flown in for a long day of learning, inundated with a data dump, and encouraged to multitask. Instead, the training begins with no travel—with a handful of brief webinars, under 30 minutes long, with agreements and appropriate methods for ensuring a single focus of attention, once a week for a few weeks. Then, when a previously scheduled meeting of company executives was planned anyway, an in-person 90-minute session is devoted to working with colleagues in small groups to generate useful connections around the new content. This represents a vast cost savings, in terms of travel and delivery, and scalability, and decreases in lost time and energy. Moreover, the learning format creates opportunities to leverage all four pillars of learning—attention, generation, emotion, and spacing. There is actually a great amount of creativity possible for cost savings, engaging formats, and reaching broader audiences when one focuses on the four principles of attention, generation, emotion, and spacing in the ways discussed. If those four elements are there, we believe the learning will last, regardless of other factors.

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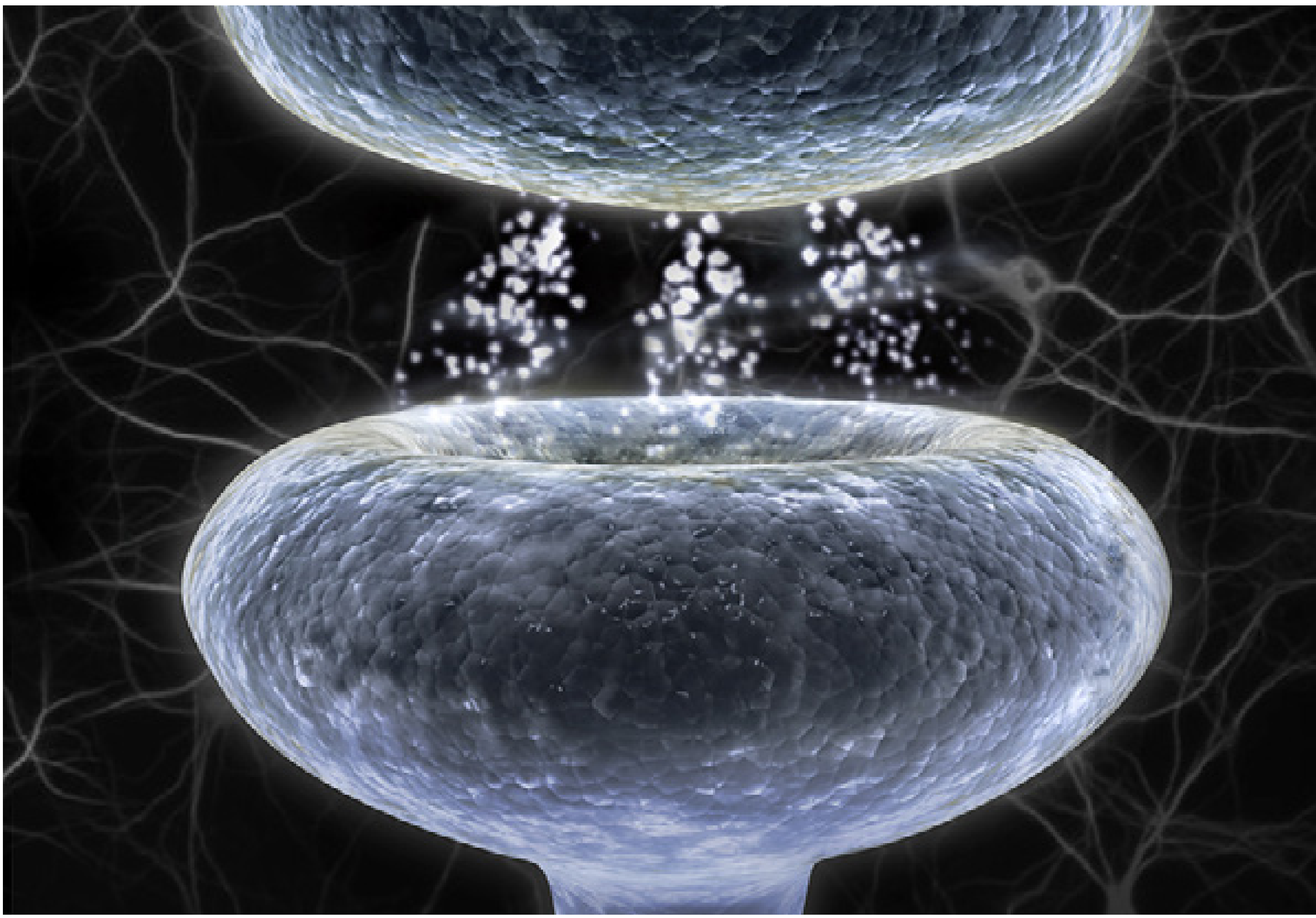

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