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THE NEUROSCIENCE OF LEARNING & DEVELOPMENT

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Crystalizing Potential

"Learning is what most adults will do for a living in the 21st century"

- Alfred Edward Perlman

You were born, and it began.

The acquisition of knowledge and information, feelings and behaviors that would combine over years to shape who you are right now. Were you to look at your progress through those newborn eyes, the feat would surely have appeared insurmountable: the fine motor skills that allow you to write and eat, the ability to speak and comprehend language, the development of complex social relationships, education, professional skills and so on.

So, in the beginning was life and then there was learning and, for the duration of our existence, there is life-long learning. In this paper, we explore the neuro-scientific underpinnings of the learning process, factors that hinder or limit our learning ability, including ways to optimise this most fundamental attribute of being human.

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Part One: How we learn

Neural networks and neuroplasticity

The human infant is born with approximately 100 billion brain cells, or neurons. That number remains relatively stable throughout life, a fact that has contributed to the long-held belief that the brain is fixed, or hard-wired, particularly post-adolescence. However, what is far from formed at birth and continues and changes throughout life, are the tens of thousands of connections that form between each one of these 100 billion neurons. The creation of these connections form neural networks and their continual restructuring and change is known as neuroplasticity.

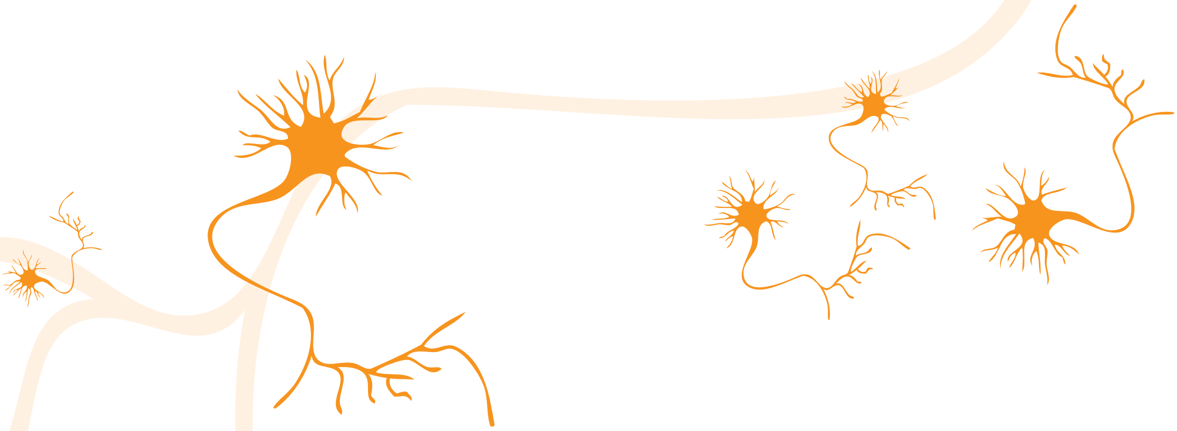
A neuron is a single cell, with a cell body, or soma, that houses the DNA and proteins that guide its functioning. Each neuron has one axon that sends messages and many thousands of dendrites that receive messages. Dendrites appear like the branches of a tree, with more branches representative of more connections. These connections represent learning.

On its own, a single neuron can achieve nothing - it takes many thousands combined to generate every action, thought or memory we have. Neurons, therefore, need to relate to other neurons. They achieve this by sending electrical signals along their axon, which, upon reaching a threshold, release neuro-chemicals into the gap, or synapse, between two neurons. If the dendrites of the receiving neuron have the appropriate chemical receptors, a connection will be formed that results in the receiving neuron firing its own electrical charge, which will be received by yet another neuron and, so, on goes the flow. One of the founders of modern neuroscience, Donald Hebb, showed that neurons that continued to activate one another in this way strengthened their connections, like a path through a forest. "Neurons that fire together, wire together" became Hebb's Law and is a fundamental principle to how we learn[1].

In this way, our brains develop neural networks that embed and store our learning. You have neural networks for every conceivable object, person, animal and situation you have ever encountered. The neural network for your perception of an orange will involve cells in different areas of your brain that code for the type, shape, feel, size, smell and taste of an orange, along with whether or not you like oranges, when and where you last had one, ways to use them, as well as abstract variants, like the colour orange. It takes thousands of connected neurons in a neural network for 'orange' to create this representation each time you see, think about or just hear the word, 'orange'. And that's just an orange.

Continual stimulation of neural pathways keeps them healthy and active

Your perceptions change over time. You acquire new information that adds to or changes what you know about things and people in your world, or how you feel about them. For example, a colleague may, surprisingly, disappoint you in their response to an issue and this gives you a new insight into their motivation or agenda. This new information requires your own neural network of this colleague to change - literally, physiologically change - in order for you to process it. This change shows the plasticity, or adaptability, of your neural connections and occurs thousands of times each day as you experience your world - at both conscious and subconscious levels.



Attention

Neural networks will be formed for everything to which we pay attention and nothing that we don't. Due to the vast amounts of information we encounter each day, we have evolved to selectively place our attention on only stimuli that are interesting or meaningful to us. Attention is the filter through which we see the world and accounts for why two people, observing the same situation, may have quite differing recollections of it: we literally see differently, based on what we attend to.

Attention requires focused concentration and is a prerequisite for neurons to be activated and neural networks to be forged. Forging new networks is energy-intensive and our brains are not designed to remain attentive for long periods of time. The brain needs down-time at regular intervals to rest and re-focus. During this time, it is also strengthening the newly-formed connections. When we push ourselves to focus beyond our natural limits, our concentration wanes, which is our brain's way of forcing a break - and we catch ourselves daydreaming.

Memory

When we pay attention, memories are formed, stored and recalled in a complex process that engages numerous regions of the brain. Without memory, there is no learning. Studies of patients with hippocampal damage (the brain region most strongly associated with the formation of new memories) show severe impairment of memory function. Such is the case of 'H.M.', who lost all declarative memory following the removal of his hippocampus as part of surgery to alleviate severe and chronic epilepsy[2]. As a result, H.M. could learn nothing new, including who he had just met, or the conversation he had just had, because information held in his short term memory was never transferred to long term memory.

Memory is typically described as a three-part process of encoding, storage and retrieval. Incoming data is held in short term, or working, memory and will be quickly lost if not consolidated. How well we encode a memory is critical to how effectively we will be able to recall it at a future point. Failure to learn can be a function of shortcomings at any of the three stages in the memory process.

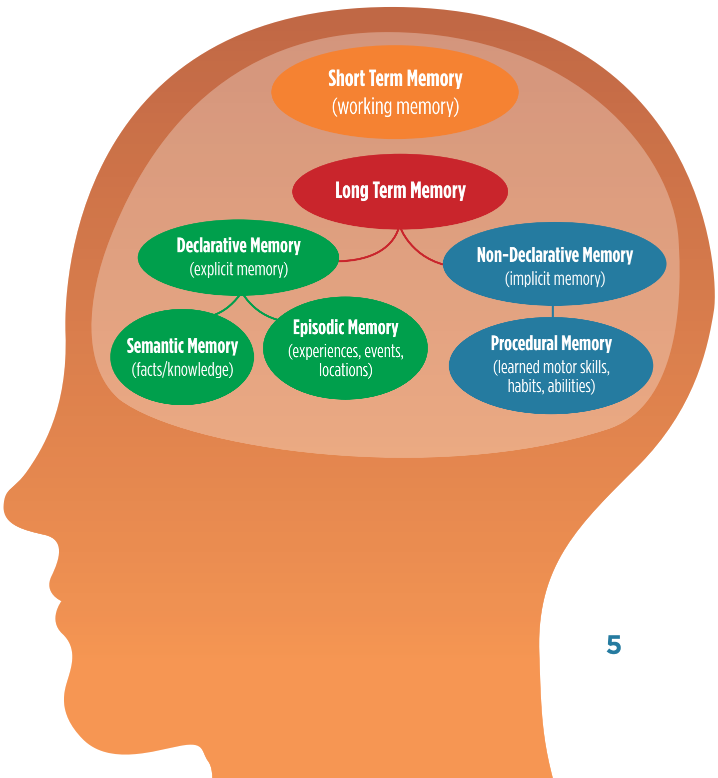
Recent functional magnetic resonance imaging (fMRI) studies show the important role of the neurotransmitter, dopamine, in the learning process. Dopamine is the brain's chemical reward and is triggered in response to positive feedback during the learning process. So, when we eat in response to hunger, feel the warmth of the sun, or receive a smile for an action taken, the brain releases a short dopamine burst to signal its pleasure and give us a quick reward for gaining it. This dopamine reward mechanism serves to reinforce the neural connections in the associated network, strengthening it with each repetition of the thought or behaviour that caused it[3]. This is the biological process that embeds learning.

Use it or lose it

The good (even great) news about neurons is that there is now clear evidence of the birth of new cells replacing old ones, particularly in the memory centers of our brain, even into late adulthood[4].

This is the process of 'neurogenesis' and counters the previous belief that we only lose brain cells and never grow new ones. This is one of the profound findings of recent neuroscience and carries very positive implications for our learning and development over time. Neurogenesis in the hippocampus means that we are capable not only of continually extending the connections between neurons as we learn, but even adding additional ones, which has been shown to occur as a result of both physical and mental activity.

The not so good news is, like the muscles in our body, the 'use it or lose it' principle also applies to our brain cells. Continual stimulation of neural pathways keeps them healthy and active, but connections weaken and recede through lack of activation. This cell atrophy is observed as we age and is accelerated by a sedentary and unstimulating lifestyle. So, neuroplasticity has a 'reverse' function. To guard against this, continual mental stimulation, or learning, is essential.



Motivation, failure and learning

Learning is not isolated to positive reinforcement: much of our learning comes from trial and error. As infants, we are learning the basics of how to live and we make numerous mistakes along the way. Being able to fail and learn from failure is an essential component of constructive learning. Harvard psychologist, Tal Ben Shahar, cites fear of failure, resulting from often unrealistic and perfectionist demands, as being one of the key detractors from learning, leading to lack of creativity and procrastination[5].

Conditions for learning

Under what conditions are learning outcomes optimised? Current approaches recognise that the dichotomy of mind and body is unnatural and, instead, emphasise the integration of the whole. In this context, learning at this level of cognition must be supported by the environmental, physiological and emotional conditions conducive to its uptake.

Imagine two individuals in two different learning contexts, where the goal in both is the acquisition of a new skill; learning to read Braille. Both students come to the task with equivalent cognitive profiles. Student A is provided with a complex manual, a passage in Braille, seated in a cold classroom with no support, no intrinsic motivation for learning this task and approaches it with anxiety and apprehension. Student B is provided the same materials, a supportive teacher, a comfortable and familiar setting and is motivated and enthusiastic about assisting his vision-impaired sister to learn to read. Who is more likely to master this task? The answer will not be determined by the cognitive ability of the two students alone, their learning occurs in a broader context.

Our learning environment must address the physical, cognitive and emotional elements in that environment

Holistic learning recognises that the brain not only interacts with incoming information, but with the entire context in which it is presented. To this end, our learning environment must address the physical, cognitive and emotional elements in that environment.

Physical

Many studies have highlighted the importance of nutrition in healthy physical and mental development. The brain draws approximately 20% of the body's available energy and increased mental demands draw more oxygenated blood into the brain as neurons need fuel to fire. Dehydration and low glucose levels drain the body and the brain of its functional necessities and, in turn, inhibit the learning process.

Recent neuroscientific research points to the role of sleep in memory consolidation. Studies have shown that hippocampal neurons activated during learning tasks are reactivated during slow wave sleep, reinforcing the neural network and consolidating the learning. In a study requiring participants to learn routes through unfamiliar streets, performance, as measured by error rates in the task, was significantly lower for those who had benefited from sleep[6]. Other studies focusing on sleep loss provide clear evidence for lower academic performance caused by reductions in both declarative and procedural memory, suggesting that the prefrontal cortex is highly sensitive to sleep deprivation[7]. So, regular good quality sleep is a precursor for memory and learning.

Cognitive

Learning is a resource-hungry brain activity and there are limits to our capacity to digest and store new material. There is a cost that comes with learning something: it takes the resources required for something else. Adult learning, in particular, requires that we channel our available resources to meet all the learning demands in our environment. We have any number of concurrent projects: related to family, work or career, leisure activities and spiritual interests, all of which require the continual integration of new information, people, processes and other demands. All these activities compete for our available cognitive capacity, so personal motivation and commitment are hallmarks of effective adult learning. This is why self-directed learning is such a key principle of adult learning[8].

Exercising our cognitive 'muscle' by building more and advanced neural networks is core to our mental fitness and also acts as a barrier to cell atrophy in later life. Cognitive reserve, the building of vast neural networks as a result of ongoing education and mental challenge, is shown to accrue over time and provide some insurance against mental decline in older age[9].

Emotional

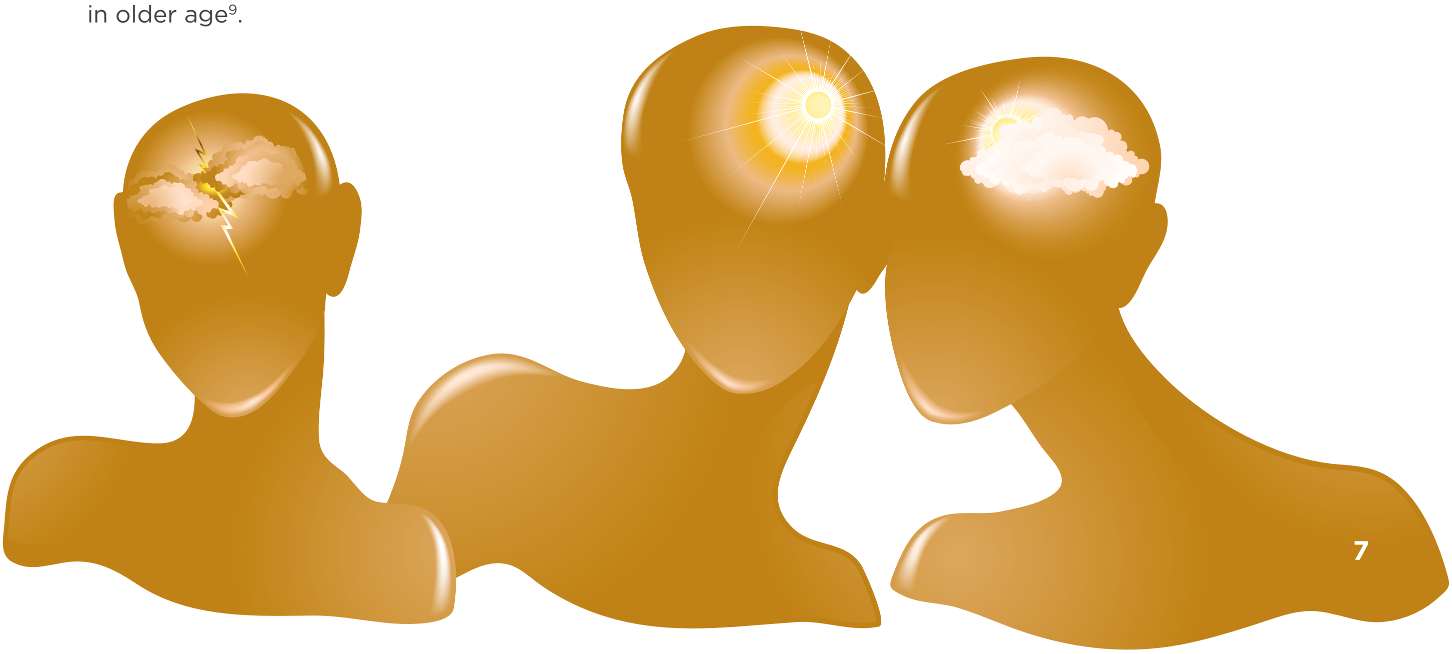
Emotions are integral to thinking and learning. The amygdala, a small almond-shaped part of our inner brain, is the seat of emotions and elicits the emotional response component of our behaviour. Amygdala activation during the encoding of a new memory enhances its subsequent retrieval[10]. This means that emotional cues linked to learning content forge a deeper and richer neural pathway than fact-based content alone.

Further than amplifying memories and consequently learning, new research highlights that emotions are actually fundamental to cognition itself. Emotion regulates where we place our attention, and therefore is essential to recruiting the neural networks on which we build our knowledge. In our earlier example of learning Braille, emotion (the student's desire to assist his sister) generates the motivation to focus his attention on the task. In this way, emotion and thinking are integrally linked.

Spotlight

We do not recall memories: we reconstruct them.

The working assumption has been that we store memories in a 'fixed' form, like video footage of our experiences - then replay the tape when we recall that memory. Emerging research shows that we reconstruct our memories each time we draw on them. And because the brain is plastic, each memory is influenced by our experiences since we stored it, our current context, and our psychological predispositions. In this regard, our memories are 'unstable' or fluid.



Collaboration

Not much of our learning occurs in isolation. Our need for social interaction is biologically based and fundamental to our survival, as well as learning. Throughout our childhood and adolescent years, we learn through direct experiences or observation of others, as well as being taught in social establishments, such as schools and colleges. Through these means, we not only create new learning, but we test and validate our thinking. Learning communities reinforce learning outcomes, increase motivation and challenge and generate more diverse solutions than individuals operating alone.

Spotlight

Metacognition: thinking about thinking

Want to have an impact on someone's career or life? Help them think better.

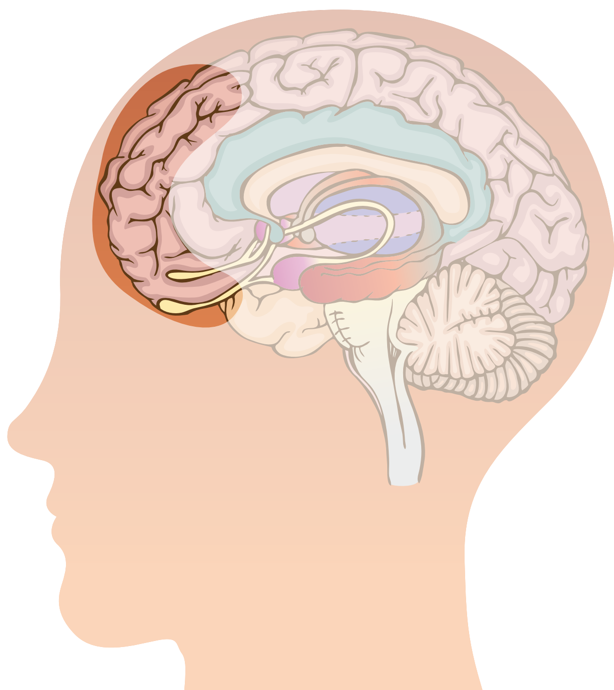
Too often we rush in to help solve the problem, but that's my solution, not yours - it may not be right for you at all. More often than not, when someone asks for help, they don't want an answer, they're just at an impasse,"What next? Why doesn't this work? How should I deal with this person?". By developing better thinking practices in others, typically by asking great questions, we build their confidence and capability. Encourage others to think.

Part Two: Limitations to learning

Prefrontal cortex capacity

The prefrontal cortex is the highest evolved part of the mammalian brain and is larger in humans, relative to body size, than all other mammals. It is the seat of our 'executive function' - our ability to think consciously, plan, organise, analyse, make decisions and comprehend complex information and relationships - it's what makes us human. Many scientists believe the prefrontal cortex is still evolving and, consequently, has not yet reached the maturity and capability of the older regions of our brain. This, coupled with the phenomenal change in human social conditions in the past two centuries, including the availability and need for much more information on a daily basis, is testing the limits of our prefrontal capacity.

The sheer volume of information to which we are exposed is a significant challenge for our processing capabilities. Neurons in the prefrontal cortex can process approximately 2,000 units of data per second - impressive, but it seems we need much more. Further, the prefrontal cortex operates via serial processing - one step at a time - so speed of processing is slower than other parts of the brain, which utilise distributed processing, and can deal with multiplicity.

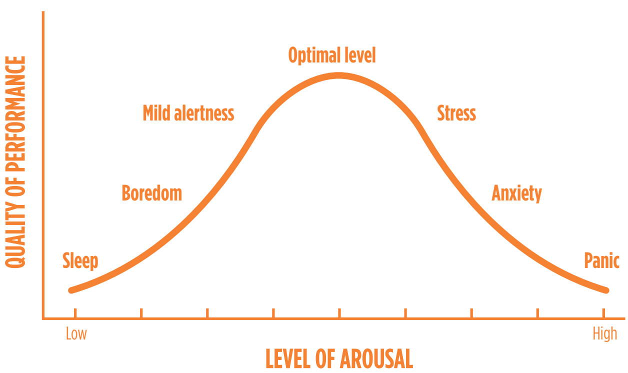


Studies of memory have estimated our abilities at more conservative levels than was previously assumed. The popular belief that we can store seven, plus or minus two, pieces of data (such as words or numbers) have been more recently revised to four and even that figure is challenged when the data to be memorised is anything complex or abstract[11]. Memory degradation, leading to compromised recall, occurs when we attempt any two cognitive tasks concurrently. This has significant ramifications in our multi-tasking world.

Stress

Our biological limitations represent a relatively fixed constraint on learning - our perceptions and interpretation of our environment is a limitation that is much more variable. Stress, like love, is in the eyes of the beholder: two individuals experiencing the same stressful scenario may respond very differently. One may deal with it pragmatically and focus on the opportunities it presents, the other feels paralysed with uncertainty, frets and procrastinates. It all depends on our perceptions.

The Yerkes-Dodson optimal arousal curve[12] explains the relationship between stress, or arousal, and levels of performance (see below). Optimal performance is achieved at the mid-point and peak of the curve. This point is characterized by a level of arousal sufficient to engage and focus the individual, optimising their skills and creating a mentally stimulating state. Below the mid-point, performance declines as a result of insufficient arousal - caused by the levels of challenge being too low to stimulate interest. Above the mid-point, the challenge becomes increasingly steep and arousal builds to levels that induce stress and anxiety, caused by the task being beyond the skills, capability and/or comfort of the individual. To feel engaged and stimulated by our work and life generally, a state of optimal arousal is necessary.



The result is that modern humans too frequently experience chronic states of stress. This puts us into the over-arousal half of the optimal arousal curve and is clearly not ideal for high performance. In a state of stress, our high energy-consuming prefrontal cortex shuts down to allow the limbic system and body to command the resources required for survival, so we stop thinking.

Neuroscience has provided insights into what occurs in our brains during periods of under, or over, arousal. Stress invokes our limbic system, which is instinctive, automatic and prepares us for a 'fight/flight/freeze' response. Our brains evolved this response for survival, so that when confronted with a life-threatening situation, our bodies would instantly redirect our energy and resources away from functions such as digestion, cell repair and thinking, to mobilising our limbs and torso and allow us to make a life-saving getaway. It served us well when we were under regular threat, hunting and gathering on the African savannah and was designed to have a short, sharp effect and cease when the immediate threat was overcome[13]. Our environment has changed dramatically since then, but our brains have not discarded this ancient survival infrastructure. Rather, they now apply it in all sorts of, often inappropriate, situations.

Spotlight

Rational thinking has not developed fully in the adolescent brain

Teenagers' brains are still maturing and the prefrontal cortex is not fully developed until late adolescence, even into the early 20s in some. It requires an adult brain to apply full logic and reason, have mindful insight and be able to reflect critically on thoughts and behaviors. Parents will say this explains a lot! It does make you wonder about the expectations we have, as well as responsibilities we give, to teenagers.

Worse still are the potential far-reaching effects on both mental and physical health that result. 'Allostatic load' is used to describe the wear and tear effects of prolonged stress on the body. High allostatic load leads to impaired immune function, loss of brain cells in the hippocampus and prefrontal cortex and growth of the amygdala (or fear function). Over time, this leads to high blood pressure, diabetes, osteoporosis, accelerates the aging process and predisposes us to dementia - we need to contain allostatic load[14].

Spotlight

Aha! The moment of insight

The brain can work in mysterious ways. You might be battling with an issue and forcing all your mental energy on it, without resolution. You've brain-stormed it, repeatedly analysed it, tossed around numerous options - nothing. Then, one morning, while not even thinking about it, the perfect answer just comes to you, perhaps in the shower - "aha"! The "aha moment" is the subject of much neuroscience research. So far, we know that a spontaneous insight requires a restful state (alpha waves) and a new neural network created by combining information from numerous, often unrelated, distributed memories.

Learning barriers

Adults learn by building on existing neural maps, or networks. Knowledge acquisition is dependent on what has already been acquired. There are three dimensions to learning and there are potential barriers that can interfere with the learning process in each of these dimensions:

1. Content

What we are about to learn must engage us to focus and hold our attention and apply prefrontal cognition. With insufficient concentration, neural networks are weak and/or incomplete and fail to form adequately, in order to embed the learning.

2. Incentive

Why we want to learn anything new must align to our motivation. This becomes a barrier if the individual does not perceive the value, lacks interest, is overwhelmed or is fearful of change. In any of these cases, there is no intrinsic incentive to learn and the dopamine reward mechanisms, necessary to stimulate and reinforce learning, fail to be activated.

3. Social

Who is involved in our learning is a critical factor for our social brain. Quality and quantity of communication, as well as interaction and support, play a direct role in learning uptake. Think about your best teachers, coaches or mentors - they inspire learning and are exhilarating. Conversely, when we have been in unsupportive environments or unproductive teams, learning outcomes are compromised.

Learning is a dynamic and complex process that is sensitive to many facets that can limit its effectiveness. Through conscious awareness of these and proactive mitigating strategies, we can enhance our own and others' learning.

Part Three: Implications for best practices

Learning today

Participation rates in adult education and training in the Western world have been growing consistently over the past 25 years. Nordic countries, including Denmark, Finland, Iceland and Norway, are close to, or exceeding, 50% participation rates. In Anglo-Saxon countries, including USA, UK, Canada, Australia and New Zealand, it is between 35%-50% (although recent data is showing the USA now moving into the above 50% category). In other European countries, the rates vary from 35% to below 20%, with northern European countries showing higher participation rates[15].

Although economic conditions have certainly impacted organisations' capacity for funding development programs, the critical business issues of leadership bench strength, accelerating the development of high potentials and building the core competencies of strategic thinking and inspiring others, remain top of the list for organisations across all industries[16].

Organisations leading the field in learning practices must integrate;

- innovative content
- engaging instruction
- blended methods
- interactive technology
- business alignment
- robust measurement
- program management[17]

No wonder few people can claim to be comprehensive role-models!

Notwithstanding, organisations recognise the need to invest in their talent in order to equip them with the requisite skills for high performance.

A model for learning

The field of neuroscience is providing both insights and pragmatic guidelines for the enhancement of learning and development practices. One example is the work of Lila Davachi, Associate Professor of Psychology at New York University, who offers the acronym **AGES** to highlight four key criteria that her research has shown to be necessary for effective learning:

A — **Attention**
Focused concentration on the task or concept without distraction

G — **Generation**
Learner to have direct interaction with the learning task to generate their own thinking

E — **Emotion**
Emotional cues associated with the learning task

S — **Spacing**
Adequate time gaps for new learning to be digested, consolidated and rehearsed

A

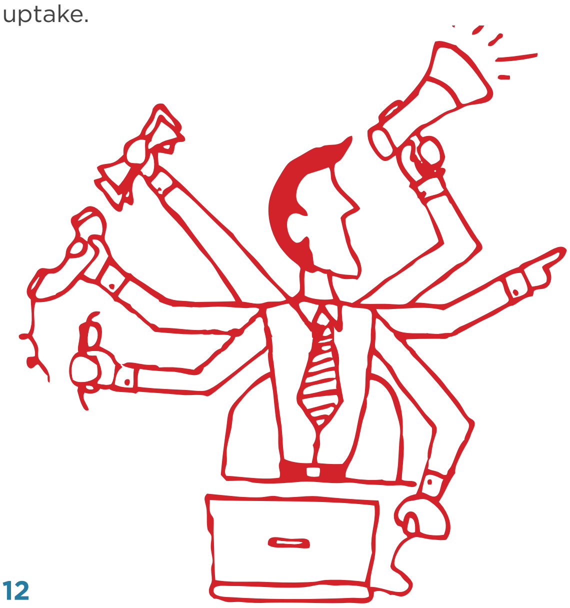
Attention

Learning something new requires focused attention. To learn new information, it must be of interest or meaningful and there must be limited distractions.

Multi-tasking requires that we attend to more than one thing at a time. Although it is physically possible to multi-task, studies show that performance on each additional task, including the first, reduces. So, multi-tasking comes at the expense of time to complete the task, or, quality of the output. Furthermore, it is almost impossible to learn something new whilst multi-tasking. This suggests that multi-tasking is best suited to habitual behaviors that require little or no cognitive input.

A recent behavioral study of three generations of Americans showed an increasing, progressive trend toward multi-tasking from Baby-Boomers, to Generation X and the 'Net' Generation, although cognitive limitations remained the same[18]. Tests of 'dual task interference', the subsequent reduction in performance by having one task interfere with another, continually provide evidence that multi-tasking compromises performance outcomes[19], although one recent study does show that participants with higher than average working memory capacity do perform better than others in multi-tasking activities[20].

The implication for designers of learning and development programs is that learners need to be in an environment that encourages and allows single matter concentration for most powerful learning uptake.



G

Generation

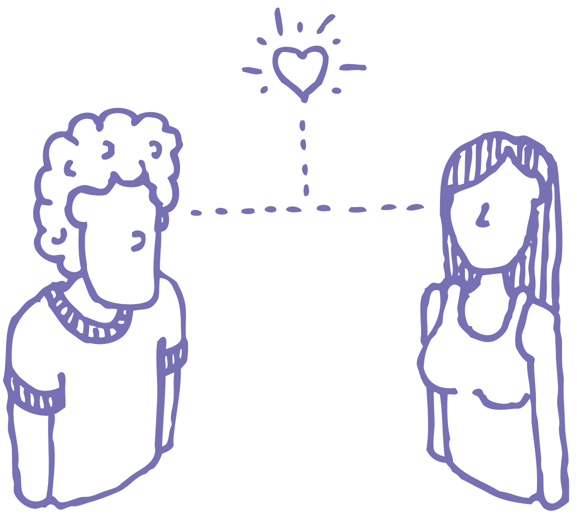
Adult learning differs markedly from childhood learning. Children absorb everything about their world in an uncensored way and place total confidence in the adults around them. Adults selectively choose what they learn based on what is relevant and of interest to them. Adults build on prior learning and take as much responsibility as they want for their ongoing learning[21]. As a result, self-directed learning methods are highly effective in adults.

"The brain is a dynamic, plastic, experience-dependent, social and affective organ" and is not just engaged in, but driving, its own learning[22]. By extension, the more the brain is proactively involved in its learning, the more effective it becomes. This is why the self-generation of ideas, strategies and actions is so critical in adult learning. With the focus on relevance and immediacy, adults learn best by taking a problem-centered, rather than a subject-centered, approach[23]. This includes defining and analysing the problem, challenging the learners' thinking, determining approaches to its resolution and encouraging team debate. The key is that ownership of the process, as well as its outcomes, is with the learner.

E

Emotion

Emotions bind memory. Like adding fuel to a flame, an emotional cue ignites more neuronal activity in more brain centers and, consequently, burns a deeper pathway. Everyone, for example, knows where they were and what they were doing on September 11, 2001, but where were you and what were you doing the day before? The vivid recollections we have of events in our life that carry rich emotional content are embedded through the activity of many thousands more neurons than is the case for 'normal' or unemotive events.



Emotion, of course, does not need to be negative. We learn better when we are in a happy, positive mood and when we are having fun. Research, for example, shows that including games in learning programs with relevant context, requiring challenging technical skills and appropriately debriefed on completion, add to the learning outcomes of all four of the Kolb learning styles (concrete experiences, reflective observation, abstract conceptualisation and active experimentation)[24].

S

Spacing

A relatively simply, but underutilised, way of improving learning outcomes is to reconsider how we 'space' content. The limitations to prefrontal cortex capacity come into direct play when we are learning, as new information must take this route to be embedded as acquired skills and knowledge. So, learning programs that begin at 8:30am and cram content back-to-back until 5:30pm, with only brief comfort and food breaks, actually contravene our biological limitations and invariably limit learning uptake. The law of diminishing returns applies to learning due to our cognitive capacity. We need to respect our biology more and work with, not against, its limitations.

With this in mind, program designers should consider staging learning content - within and across days. For example, a leadership program that introduces new content, such as leadership models, in the morning session, then applies this content all afternoon in interactive and engaging ways, will achieve a much better learning outcome than a full day of new content alone. Programs that stagger sessions over consecutive or even intermittent days allow for the benefits of memory consolidation during sleep to improve outcomes.

Stress and learning

The biological evidence is clear: stress and learning do not mix. Although stress is a subjective response and will, therefore, vary by individual, program designers should aim to minimise potential stress by:

- ensuring content is pitched at a level that is challenging, but within the capability of the target audience
- providing a supportive environment in which 'failure' is part of the experience and not to be feared
- ensuring adequate food, water, light, temperature, ventilation and physical space to meet physiological needs
- adding 'brain breaks' for mental rest and physical activity for re-oxygenation
- ensuring the audience can relax, laugh and interact informally.

Spotlight

Mindfulness versus mindlessness

The growing field of mindfulness is drawing a biological link between the realms of science and spirituality. With its origins in Buddhist meditation, fMRI brain scans are showing how brain waves can be altered through mindful meditation to induce enhanced thinking states. Beta brain waves, indicative of a busy, 'noisy' brain, make focus and concentration difficult through over-stimulation. The more relaxed alpha wave state can be activated through meditative practice, leading to mental acuity and alertness.

Allowing for these components will be challenging for some instructional designers, as well as organisations where training efficiency, in terms of maximum material in minimum time, are the program drivers. If learning effectiveness replaces efficiency as the measure, brain-friendly approaches will be justifiable.

The biological evidence is clear: stress and learning do not mix

Informal & collaborative learning

We are always learning, sometimes whether we intend to or not. Directed, intentional learning is usually formal in nature, such as reading professional material, attending a seminar or listening to a podcast. But, in fact, most of the learning we experience is of an informal nature and usually involves others.

The Bersin & Associates Learning Leaders® 2010 report states that "this year, the biggest buzzword in training is informal learning". Recognition that the majority of learning actually occurs outside the classroom/training room/lecture theatre has come to the fore at a time when resources are tight and the value of social interaction, coaching and mentoring have become prevalent - it's like the perfect storm.

Consistent with this trend, many organisations recognize the simple 70-20-10 rule:

70% of learning occurs informally and on the job;

20% of learning occurs through observation of others;

10% of learning occurs through formal training.

This also highlights the collaborative nature of learning; potentially 90% of all learning occurs through interaction at some level with others, which makes whole-brained learning possible by tapping into the varied approaches and thinking styles of others in a group.

Technology and learning

It's hard to think about learning and development in 2011 without considering the role of technology. With the proliferation of high quality online learning content supplied by many of the world's most respected institutions, the availability and accessibility of knowledge is unprecedented. Most organisations have, or are moving toward, e-learning formats to augment and, often, replace traditional classroom-based training.

Although learning management systems (LMS) have been available and popular for over a decade, their effectiveness has been mixed with uptake and engagement by learners variable. Appealing user interfaces, content quality, ease of access and interactive functionality have been criticisms of early LMS models. Learning continuance, the ongoing utilisation of e-learning beyond initial uptake, has seen steep declines. User acceptance of online learning technologies is proving to be a key facet for predicting continuance intention. Deci & Ryan's self determination theory has been used to explain motivation to persevere with e-learning programs. Research has shown that learning continuance is strongly influenced by the perceived usefulness, playfulness and ease of use of the technology[25].

As e-learning moves toward m-learning (e-learning gone mobile), there will be even fewer impediments to accessing learning content. Studies are already showing advanced learning results when mobile access is available[26]. This is a function of devices and connectivity. Interactive video, already being trialled extensively in the education sector, also shows promising efficacy in learning and will most likely be a staple of future learning programs[27].

A further challenge for technology in learning is to connect not only individual, but collective minds to leverage the effects of collaboration in learning. The social interface is likely to be a key differentiator in the future development of learning technologies.

End note

The brain loves to learn - fundamentally, that is its job. From the earliest conversion of the basic sensory input an infant sees, hears and feels, to the ongoing adaptations and growth we experience throughout adult life, our brains are changing, restructuring and learning. When you go to sleep tonight, it is with a brain that has changed as a result of today's learnings and when you wake up tomorrow, with new consolidated memories, more learning awaits you.

Neuroscience has not discovered that we learn - this much we already knew. What neuroscience casts light on is how the brain acquires, stores and uses information, and what intrinsic and extrinsic factors can limit us from optimising this process. By understanding more about how humans learn, educators and organisational learning and development professionals can tap the learning capacities of the brain that will drive the learning results toward which they strive.

In a world seeking to build talent and drive exceptional performance, organisational initiatives guided by scientific breakthroughs will combine to crystalise the potential of our talent.

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Sylvia Vorhauser-Smith is Senior Vice President of Global Research at PageUp People. She is responsible for driving thought leadership in the field of human capital management for global organisations facing cross border expansion and growth.

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She is a regular national and international speaker on neuroscience, talent and human capital management, having addressed audiences in Boston, Singapore, Kuala Lumpur and across Australia. Vorhauser-Smith holds a Bachelor of Business and Graduate Diploma of Psychology from Monash University, Post Graduate Certificate in NeuroLeadership and is currently completing her Master of Science in NeuroLeadership at Middlesex University.

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