Novelty as a strategy to improve learning

Educators and researchers are constantly looking for strategy to improve learning and memory. "Pills of intelligence", natural products that could improve memory performance, and medicines that promise the improvement of cognitive functions have been always desired by some and promised by many.

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Author/s:

Pâmela Billig Mello-Carpes
Professor, Federal University of Pampa (Unipampa), Brazil

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Learning how to learn

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Executive Summary

- Educators and researchers are constantly looking for strategy to improve learning and memory.
- Short- and long-term memory differs on the duration of memory and neurobiological processes involved in each one.
- When a memory is being formed the context and emotional involvement can influence it.
- The inclusion of an exciting novel experience in learning context can promote neurobiological changes that favour the improvement of learning/memory.
- The novelty's effects on memory can be explained by the morphological alterations in the communications between neurons.
- Novel stimulus promotes gene and protein expression on hippocampus, what suits as substrate to consolidate memory.
- Novelty inclusion on classroom is possible and improves students' learning of specific contents.

Introduction

Educators and researchers are constantly looking for strategy to improve learning and memory. "Pills of intelligence", natural products that could improve memory performance, and medicines that promise the improvement of cognitive functions have been always desired by some and promised by many. However, until now, there is no miracle that guarantees enhancements of learning and memory.

Neuroscience research demonstrates that there are important factors that regulated the learning (such as attention, emotions, and sleep), and that some lifestyle factors (such as physical exercise and healthy eating) can positively affect learning[1]. The fact is that when a memory is forming the context and emotional involvement can influence it.

Short- and Long-term Memory

Memory is one of the main cognitive functions supported by the brain; it consists of the acquisition, consolidation and recall of information. The acquisition of information through experiences and from the environment is a major part of learning – the learning context is very important to determine the strength of the memory trace. In neurobiological terms, during the learning, the stimulus set promote the activation of synapses[i], which could be modified to store the information for future recall.

The learning occurs by the reception and interpretation of external and internal stimuli (as images, sounds, tastes, inner sensations…), and, depending on the significance and relevance of these stimuli, a short and/or a long-term memory can be formed. The short-term memory (STM) can last from minutes to some hours, and does not generate permanent changes in our brain, but it is fundamental for us to manage the information while long-term memory (LTM) is being formed[2,3] (figure 1). LTM, in its turn, can last from some hours to many years. It can last long-life. It is possible considering that LTM involves structural brain changes to the information storage in different brain structures[3].

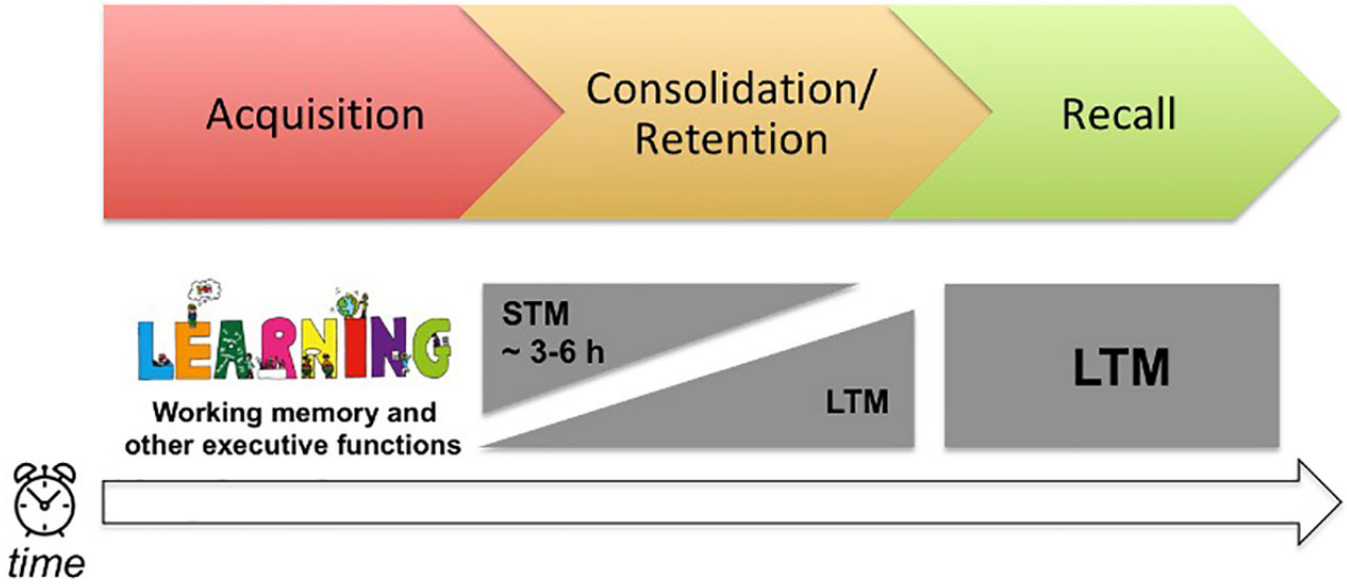

Fig 1. The learning occurs by the reception and interpretation of external and internal stimulus (as images, sounds, tastes, inner sensations…), and, depending on the significance and relevance of these stimuli, a short and/or a long-term memory can be formed. The short-term memory (STM) can last from minutes to some hours. LTM last from some hours to many years. It can last long-life.

Thus, although STM and LTM share some common initial mechanisms, they do differ from one another, especially in the neurochemical processes that are associated with their formation and consolidation[2,3]. In STM processes the brain circuitry involved is broad, however, permanent modifications are minimal and neither the synthesis of new proteins nor gene expression on neurons are necessary. On the other hand, to be available for future recall, LTM involves several processes after the acquisition. These processes include memory consolidation, when several neurochemical cascades begin. It is believed that the initial step of LTM consolidation involves the release of neurotransmitters[ii], what initiate a cascade of cell signalling[3].

Novelty

Our experiences and environmental interactions will impact our brain, and lead to some brain changes, that could be brief and transient, or lasting and permanent. The significance of the experience will determine this, and significance depends on the nature of the interaction and its utility or applicability to life[4]. Additionally, behavioural, hormonal and neural influences acting during memory acquisition or consolidation can regulate it, positively or negatively[5].

A novelty corresponds to something that is new and exciting, and, in this sense, captures our attention and interest, activating important neural pathways. Novelty has been widely investigated as an strategy to promote a better learning[5,6,7,8].

Exposure to novelty may occur, for example, by exposure to an initially unknown environment[5,9,10], to a new flavour or a novel experience. This strategy has been studied for its ability to improve memory in both humans and animals[5,6,7,8,9,10]. The neurobiological basis of novelty use to improve learning and memory are related to its modulation of biochemical cascades that are associated with the LTM consolidation.

Scientists have found that one stimulus that normally was able to promote a STM (as an theoretical non-contextualized history content, for example) can promote LTM consolidation when associated to novelty[9] (class in a different place, or a different practical activity after the class, for example), a phenomenon that has been explained by the Synaptic Tagging and Capture (STC) hypothesis proposed by Frey and Morris in 1997[11].

The Synaptic Tagging and Capture and the Novelty

The STC hypothesis was initially tested in electrophysiological experiments performed on neurons from hippocampus[iii] and proposed to describe the synaptic changes that occur during memory formation. The STC proposes that when a synaptic

pathway is stimulated, two dissociable events occur: a phenomenon known as early long-term potentiation (LTP)[iv], which is the main neurophysiological and cellular model for early learning and memory formation (lasting a few hours), and the tag (marking) of the stimulated synapse, a temporary state that allows the synapse to be susceptible to long-lasting modifications[12](Figure 1).

In parallel, if the stimulus is strong enough, there will be the synthesis of plasticity-related proteins (PRPs) that will be captured only by the synapses tagged (Figure 2). These PRPs, in turn, will provide support for this potentiated state and the formation of a late phase of LTP (lasting from days to weeks), which allows the LTM consolidation[9,12,13]. However, if the stimulus is not strong enough, there will be no synthesis of PRPs and, even if marked by the tag, the previously activated synapse gradually returns to its basal condition, unenhanced and unmarked state[9,13].

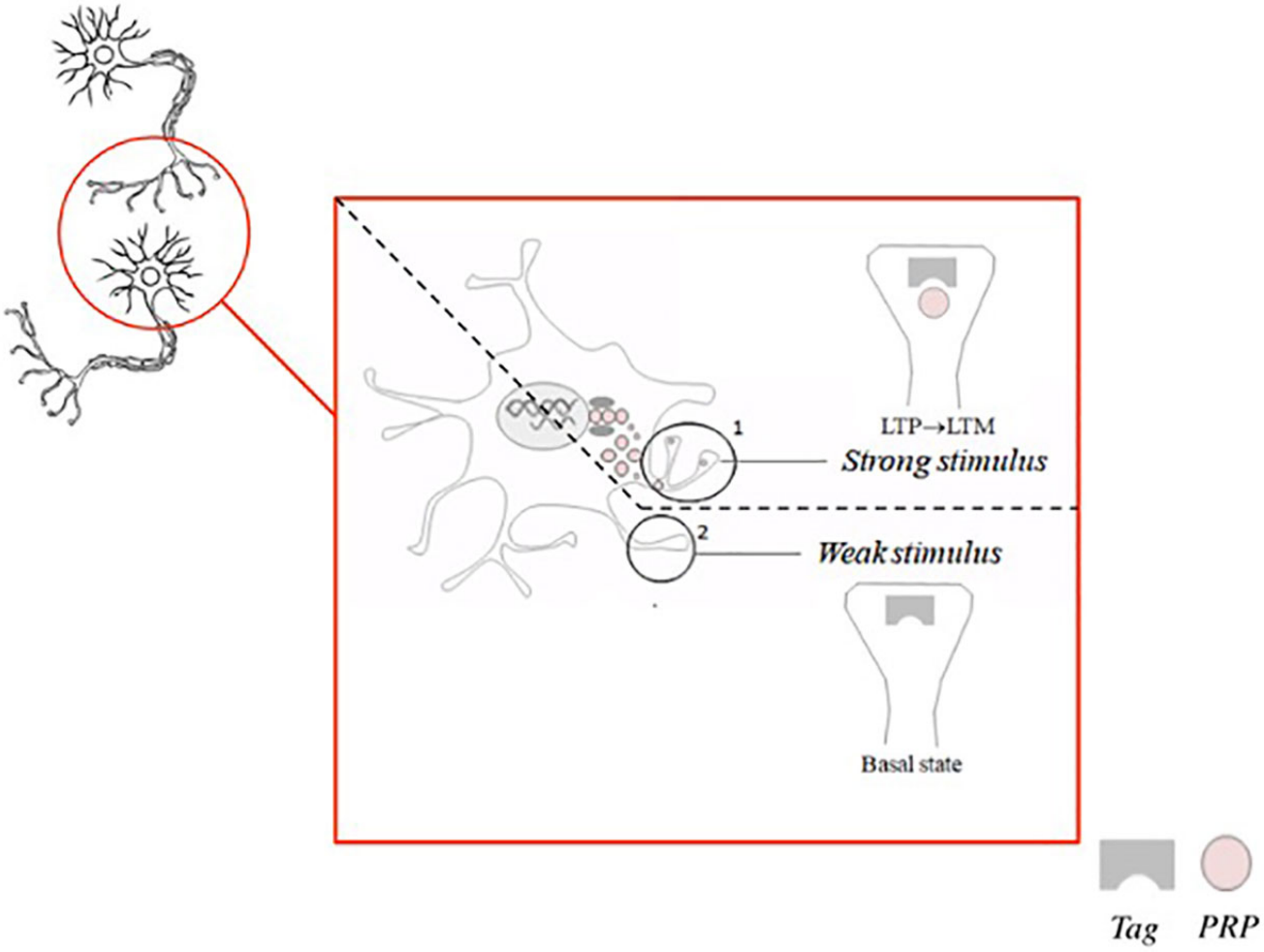

Fig 2. After a synaptic stimulation, two phenomena occur: the Long-Term Potentiation (LTP) and the tag of the stimulated synapse, a temporary state that allows the synapse to be susceptible to long-lasting modification. If the stimulus is strong enough (neuron 1), there will be the synthesis of plasticity-related proteins (PRPs) that will be captured only by the synapses tagged and provide support for this potentiated state and the formation of a late phase of LTP and Long-Term Memory (LTM) consolidation. If the stimulus is weak (neuron 2), the synapse will be tagged, but will not produce PRPs, so, it will go back to its basal state.

But how the novelty could favour the LTM and what is the relationship with STC? The idea is that a novel experience is a behavioural event that is strong enough to induce protein synthesis and an LTM[13]. If it is associated with a learning experience that was able to promote only STM, it would be possible that they share the PRPs whose production was induced be novelty, so, both experiences could promote LTM (Figure 3).

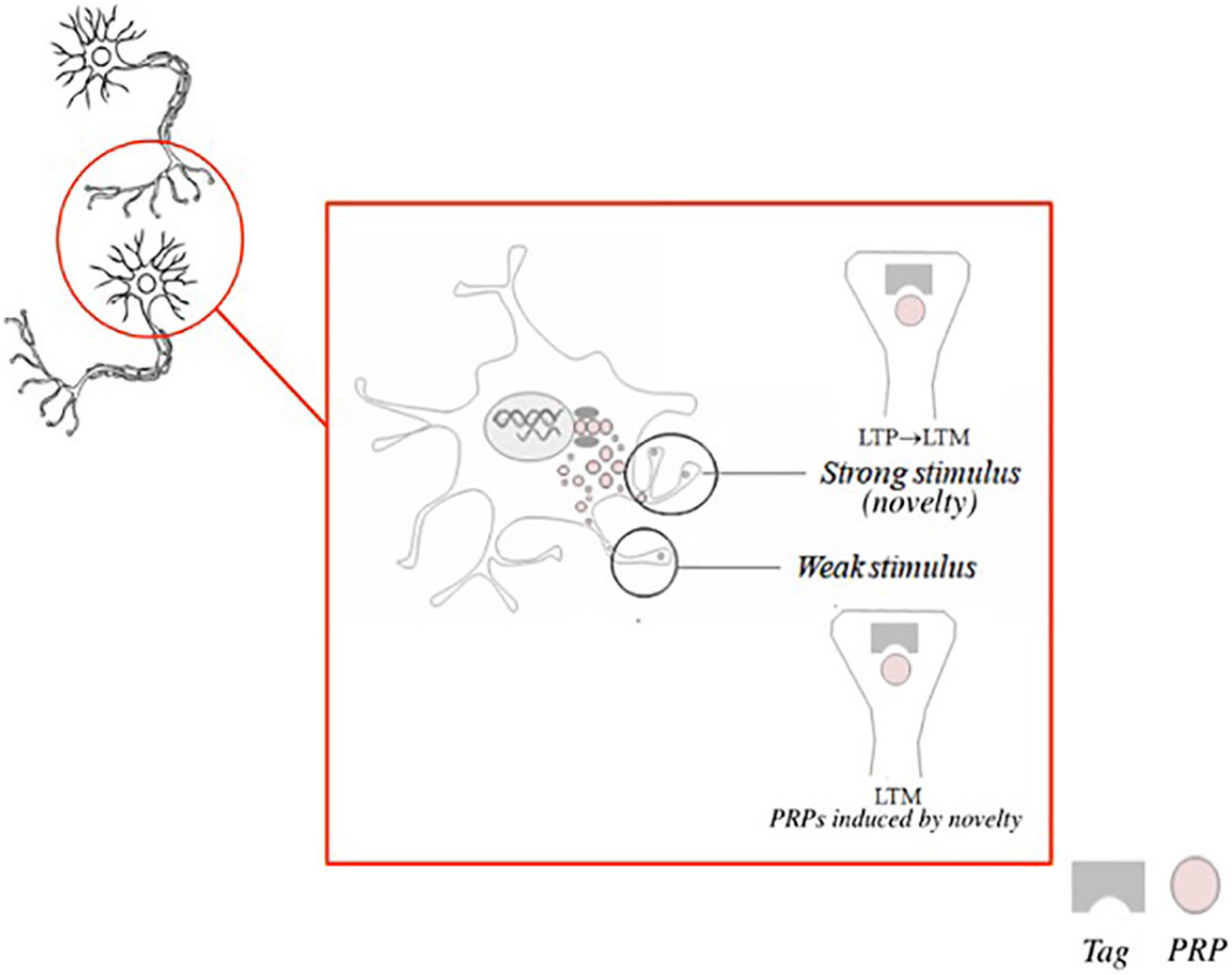

Fig 3. A novel experience induces a strong synaptic stimulus that induces plasticity related protein (PRPs) synthesis and capture, and so, LTM consolidation. If it is associated with a weak-learning experience, they can share the PRPs whose production was induced be novelty, so, both experiences could promote LTM.

Therefore, it is important consider that the novelty effects is time-dependent. Studies with humans and animals evidence that its effects can be observed when the novel experience occurs in a time window close to the learning session (varying from ~1-2h before to 1h after the learning session)[5,10,14].

Novelty effects on other cognitive functions

Research suggest that the effects of novelty on STC and LTM consolidation are mediated by brain responses that lead to neurotransmitters release[10,15,16]. Anyway, in addition to learning effects, exciting novel experiences can affect other cognitive functions, as attention, perception and motivation[7,8].

Novelty can improve temporarily the perception, an effect that can be explained by the activation of amygdala[v], what increase the initial sensorial perception. Additionally, the novelty can increase arousal, effect that is related to noradrenergic activation. Despite the increase of noradrenaline, novelty promotes dopamine release, which can improve motivation and reward processes[7,8]. All these effects directly and indirectly contribute to learning and memory improvement.

Still, the improvement induced by a novel experience is not derived from an increase in the arousal state or from lowering the threshold to learn, since the novel experiences can improve LTM even when they occur after the acquisition of the information to be remembered[5].

Novelty uses in educational context

Although direct evidence for a link between novelty and increased brain plasticity comes from electrophysiological and animal studies, evidences of novelty effects on learning and memory from studies with humans has been found[6,8,17]. In educational context, novelty was investigated as an alternative teaching strategy to improve students' learning and performance, especially in cases in which is more difficult arousal the students' interest[5].

An interesting and well-designed study investigated the effects of a novel experience in narrative (verbal) and graphical (visual) learning of elementary school children[5]. The researchers proposed a novel experience after a learning session in educational context: the students were unexpectedly taken from the class to a different place (inside the school, but not usually frequently by the students), where they performed an activity never experienced before (a science experiment or a music class), guided by a different teacher. They were required to attend to the activity (lasting 20 minutes), and stimulated to participate and interact. The researches verified that the novel experience improved the memory of literary or graphical activities. Briefly, to evaluate the literary memory, a teacher read a short story to the students in the class (for some students the story was associated to a novelty and for others no); memory was evaluated using a list of 10 questions related to the story read in the following day. To evaluate graphical memory the Rey-Osterrieth's complex figure test was used – this test involves the presentation of a complex geometric figure to students, which had 2 minutes to copy the picture – the teacher collected the drawing, and in the following day the students should draw it again (for some students the figure presentation and copy in the first day was associated to a novelty and for others no).

As mentioned, the students exposed to a novelty present better memory than the others. Interestingly, this effect was strictly dependent on the time of novelty exposure. When it was developed 1 h before or 1 h after the learning session, the improvement was observed, but when it was 4 h after or before, no effects were observed.

The interesting about this research is that the effects were observed for different types of memory (verbal and visual), and with two different types of novel stimulus (music and science lessons). Additionally, when the students were informed that these novel activities would occur, participated in the activity previously (so, it is not novel anymore), or just moved around the class, no improvement was observed – which specify the novel-dependent effect.

So, the novelty has an important relevance and application in educational context; novel experience could promote enhancements on learning and memory within the school environment[5]. It can be applied during scholar hours as an adjuvant of other information acquired some time before or after it to facilitate the LTM consolidation of contents or concepts taught, especially that ones that generally demand a great effort from students. Additionally, it is a quickly applied non-expensive methodology that could be easily incorporate in the school schedule.

[i] Synapses correspond to the local of contact (not necessarily physical contact) between two neurons. In adult brain chemical synapses are found, so, the neurons do not have physical contact, but use neurotransmitters to send information.
[ii] Neurotransmitters are endogenous chemical messengers produced by neurons that allow the neurotransmission (synaptic transmission), it means, the communication between neurons.
[iii] The hippocampus is a structure of temporal brain lobe that is intrinsically related to memory acquisition and consolidation.
[iv] Long-Term Potentiation (LTP) is a lasting improvement in synaptic transmission that is considered the basis of memory consolidation and is highly related to neuroplasticity.
[v] The amygdala is one nuclei of neurons located deep in the temporal lobes of the brain. It is related to emotional memory processes and has intrinsically connected with hippocampus.

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