Exams as a source of stress: How assessments may affect learning, through stress

Stressful situations such as examinations may affect the learning process and memory in different ways. When students are required to analyse novel information relevant to the examination and apply knowledge to a novel situation, such evaluations may contribute to reinforcing skills and consolidating memory.

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Executive Summary

- Assessment and examination methods have a profound impact on how students study, what they learn and the way they subsequently use new knowledge, ranging from mostly factual knowledge to abilities and skills, and from surface learning to deep learning.
- Traditional exams and evaluations can exert a stressful pressure on students which may affect both the learning process and memory formation in different ways. However, responses to stress depend on the temperament of each individual, among other factors.
- The effects of stress on memory depend on the particular memory phase, for example, encoding, consolidation or retrieval, as well as on the temporality of the stress with respect to the learning activity or memory stage.
- Usually, the temporality of exams with respect to memory phase or learning activity, makes the stress that such evaluations may generate detrimental to memory consolidation, thus making the overall learning process less effective.
- When examination is coupled with the acquisition of new learning and knowledge perceived as relevant to the situation, or when learning and testing take place in the same context, recall is spared from the damaging effects of stress. These methods may contribute to consolidating memory, making for a more efficient learning process.

Introduction

One of the major ongoing questions in education is the role of exams, i.e. what purpose do they serve. Assessments are used to verify whether a student is qualified, although they can be used for other reasons as well, for example progress monitoring and as an educational tool to influence the learning process including memory consolidation, for example through feedback with students. Exam qualifications may be used as selection criteria to determine students' access to particular high schools or university studies through a numerical classification that can be interpreted by some as an educational "end point", if a sufficient rating is not achieved, although for others, it can serve as a stimulus to further progress. Temperamental disposition towards stress and anxiety may contribute to these different responses[1], but the examination method used, as well as the so-called testing effect, may also play a part[2,3].

The examination method and question typology used to test students' knowledge on any given subject may also have a considerable impact on how and when students study, what they learn and the way they subsequently use new knowledge[4]. Moreover, official examinations, which depend on the educational policy and legislation of each country or region, such as those allowing access to higher studies (i.e., entry into university), can influence the way teachers teach[5] and, consequently, the way students study and learn. Put simply, if an assessment is mainly a test of factual knowledge, students will be expected to learn, memorize and recall facts and details. Where an assessment requires the ability to interpret, give examples, summarize, compare, explain, apply, analyse, evaluate or synthesize the students will have to focus more on skills. Of course, even if the assessment is mainly of factual knowledge, students can still learn how to interpret, compare, apply, analyse and so on, but the tendency will be to focus more on facts and details to get the best qualification. Conversely, if the assessment is mainly of abilities and skills, students still have to learn facts and details (otherwise they will not have sufficient material to apply their skills to), but they will tend to focus more on these abilities. The same can be said for other kinds of assessment, including those that combine different examination systems. The use of any specific method or combination of different methods, i.e. fact-based or skill-based exams, as well as the precise form in which they are designed (essay, multiple choice test, open-books exam, etcetera; see below for discussion on examination methods) depends on diverse factors such as educational policies, education centres and teaching systems, and it varies worldwide.

Alongside these considerations, exams and evaluations may exert a stressful pressure on students. In fact, stressful events are quite common in educational settings, for both students and teachers. Stress, however, can have a critical adverse impact on learning and memory processes[6,7] and, taken to an extreme where it becomes chronic, it may also contribute to some brain disorders such as major depressive disorder or post-traumatic stress disorder[8]. Many studies have been conducted to clarify the effects of stress on learning and memory, both in humans and using animal modelling systems. The effects of stress are complex, producing both enhancements and impairments to memory and learning as well as to the control of executive functions such as the attentional systems, working memory, inhibition (emotional management) and cognitive flexibility, among others[9,10], depending on the specific cognitive process, the student's developmental stage (from childhood to adulthood) and temperament, etcetera[6,11] (se below for discussion on these issues).

Thus, although assessment is crucial to monitor the effectiveness of both teaching and learning and to verify whether a student is qualified, at the same time, assessment methods shape how students approach learning, how much they learn and what (i.e., the content) they learn[12,13]. In this context, the stress generated by examination and evaluations may affect the learning process from "inside", that is, from neural mechanisms linking stress responses and learning. Consequently, teachers, students, testers, curriculum designers, policy makers, institutions and administrations are all, in some way, affected by testing and examination methods.

In this brief, the effects of exams and evaluations on stress responses and consequently on learning will be discussed. It is not intended to be a review of current evaluation systems or educational policies around the world, which differ substantially depending on national and regional policies[14], educational traditions, available technical resources, etcetera, but to provide ideas and hypotheses that may help in rethinking the role exams may play and which kind of exams can best fulfill this function, to inform educational policies and teaching practices, and to guide future research in educational neuroscience towards development and progress in this area. To reach this goal, this brief will first summarize how the typology of exams may influence learning and, from there, it will consider the effects of stress on memory consolidation and executive functions in different scenarios.

How the typology of exams may influence learning: an overview

Memory retrieval, which is a crucial cognitive activity during examination, is an active process that can alter the content and accessibility of stored memories. Although this *testing effect* often becomes visible only over time[2,3], it is of potential relevance for educational practice, as it has been shown that memory retrieval fosters better retention than mere studying[3](e.g. the use flashcards to study, which depend on retrieval). However, stress, a physiological response to potential threat, that is quite common during examinations as well as during the process of preparing for examinations, may also affect the learning process and memory formation in different ways[6,7], which, in turn, may mean that assessments can produce contradictory effects on these processes.

Various forms of examination and assessment are traditionally used, each of which has specific characteristics which may influence teaching and learning in different ways[15]:

– Written exams, which may include short-answer and essay questions. Short-answer questions are mainly used to test how students recall specific facts (although they don't have to be, as for example it is quite easy to have a short answer question that asks students to compare and contrast two things). Conversely, essay questions may give a better assessment of how students have understood a subject and their ability to apply their knowledge and perform analysis, comparison, evaluation and synthesis (see the annex for an example).

– Multiple-choice tests, which are mainly used to focus on detailed factual knowledge.

– Open-book exams, in which students are allowed to use textbooks and other materials. This can be helpful to test students' understanding and ability to apply knowledge and select relevant information.

– Computer-based assessment, which can be formed of multiple-choice questions, but may also include interactive problems students have to elaborate on using the software, thus combining factual knowledge and skills.

– Take-home exams, in which the tasks are used to test students' understanding and ability to apply knowledge and select and synthesize relevant information, possibly decreasing the pressure of having a very limited time to solve them.

– Oral examination, which is useful to test the students' knowledge and understanding of a topic in a dynamic and interactive way, including their skills of application, analysis, integration, argument and synthesis of information. Moreover, the direct feedback in oral examination provides opportunities for students to learn immediately from the examination, and it has also been shown that presenting knowledge aloud contributes to its consolidation[16]. However, some temperaments may impair students' performance when facing oral examination.

– Report writing and oral or poster presentations of tasks performed, in which the ability of students to perform tasks and apply knowledge to unfamiliar situations, including analysis and synthesis, as well as to write and present the outcomes, is tested.

The first work on the effect of written examinations on learning and on retention of learning dates back to 1938[17]. One of the main conclusions of this seminal work is that "the use of examinations stimulates achievement to a significant degree, […] but there is as yet no evidence to show that the greater achievement […] persists after six weeks to three months". Much more recently, several works have analysed the effects of exam typology on how and what students learn. For example, comparing an end-of-course essay assignment to a multiple-choice examination among second-year education students from the University of Sydney[4], it was reported that students were more likely to employ surface learning approaches in the multiple-choice examination context and to perceive multiple-choice examinations as assessing knowledge-based intellectual processing. In contrast, students were more likely to employ deep learning approaches when preparing their essay assignments, which they perceived as assessing higher levels of cognitive processing. Poorer performance in the essay assignment was associated with the employment of surface learning strategies, and poorer performance in the multiple-choice task was associated with the employment of deep learning strategies. Surface learning strategies may be defined as memorizing solely what is needed for an exam[18]. It is said that students engaged in surface learning tend to be more passive learners and to see learning as coping with tasks so that they can pass the assessment[18]. Conversely, students adopting a deep learning approach seek to understand meaning, are more likely to have a genuine curiosity about the subject, and its connections with other subjects, building on their current learning[18]. It is said that these students may enjoy social learning, including discussing different points of view[19]. It has also been shown that active learning increases student performance in science, engineering and mathematics[20], and that problem-based learning improves deep learning[21].

In another work, focused on the effects of tests on language studies[22], the positive effects or influences were summarized in the following points: (1) Tests induce teachers to cover their subjects more thoroughly; (2) Tests motivate students to work harder to gain a sense of accomplishment and thus enhance learning [although mainly factual learning], and (3) Good tests can be utilized and designed as beneficial teaching-learning activities so as to encourage positive teaching-learning processes. In the same way, the following negative effects were reported: (1) Tests encourage teachers to narrow the curriculum and lose instructional time, leading to "teaching to the test"; (2) Tests induce anxiety in both teachers and students and distort their performance [see discussion about stress and learning, below]; (3) Students may not be able to learn real-life knowledge, but instead learn the discrete points of knowledge that are tested, and (4) Cramming will lead students to have a negative association with tests and will accordingly alter their learning motivation.

One way to take advantage of the positive effects of different examination methods and decrease the incidence of the negative ones is to use a combination of the different examination methods to conduct assessments. Although, currently, most pedagogical strategies and educational policies do utilize this idea, the author feels it is important to emphasize these aspects as this brief is intended for use worldwide. It is also worth noting that examination methods focused on testing the ability to apply knowledge to particular situations and to perform analysis, comparison and evaluation can be applied not only individually but also to groups of students, thus testing their capacity for working collaboratively[23-25]. This may also be useful for assessing teaching practice where this strategy (collaborative work) has been used during teaching. However, the common denominator of all exams is that for some or even many students they generate stress, which may have contradictory effects.

Finally, it is important to note that the use of the above-reported variety of examination methods depends not only on educational policies and traditions, but also on the availability of the materials and instruments needed, such as textbooks for open-book exams, computers and internet connectivity for computer-based assessments, appropriate spaces and proper parental or caregiving support for take-home exams, etcetera. These factors, in turn, are also, but not solely, influenced by regional differences and socioeconomic status[26].

Memory retrieval and memory consolidation

As stated above, memory retrieval, which is a crucial cognitive activity during examinations, contributes to memory consolidation. Memory consolidation refers to the process by which a temporary, labile memory is transformed into a more stable, long-lasting form (Figure 1). It was first proposed in 1900[27] to account for the phenomenon by which learned material remains vulnerable to interference for a period of time after learning. During memory consolidation, that is, the gradual reorganization of the brain systems that support memory[28,29], the hippocampus guides the reorganization of the information stored in the neocortex[30]. The hippocampus is part of the limbic system and plays an important role in the consolidation of information from short-term to long-term memory and in spatial memory that enables navigation. In turn, the neocortex is part of the human brain's cerebral cortex where higher cognitive functioning, including executive functions, is thought to originate from. In other words, memory consolidation refers to. Moreover, under some conditions, long-term memory can transiently return to a labile state and then gradually stabilize again, a phenomenon termed reconsolidation[31-33]. It is worth noting that the dynamic nature of long-term memory[34] makes it reconstructive every time it is evoked or used, but also

vulnerable to error, as in, for example, false memories[35]. Although much of this effect is not to the extent of false memories, what is important is that the act itself of recalling the memory changes the memory.

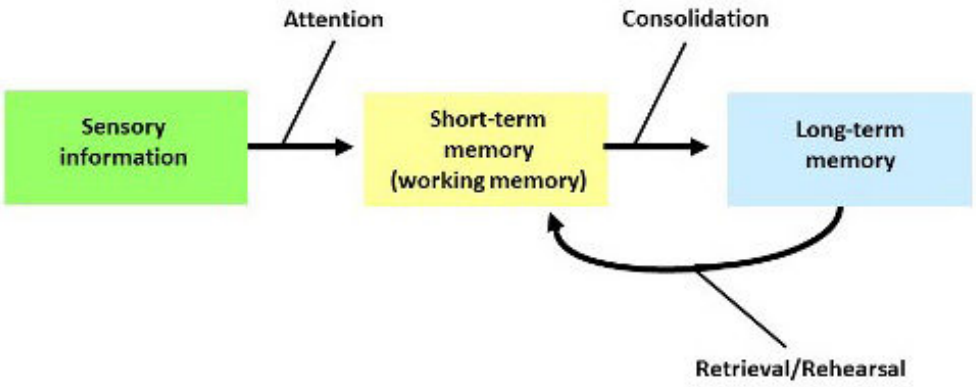


Figure 1. From sensory memory to long-term memory: the role of memory retrieval in memory consolidation.

This point highlights the importance of evaluation methods that do not disrupt previous learning, but instead contribute to its growth and consolidation, as in, for example, when students must analyse novel information relevant to the examination and apply knowledge to a novel situation. It is worth noting, however, that the putative disruption effect may be used to induce conceptual changes when needed.

In this schema, retrieving newly learned information from memory is an active process that consolidates information, and thus it decreases the incidence of forgetting[36,37]. This effect is specially relevant when combined with spacing between learning and successive retrievals[38,39]. The question of forgetting curves was first examined at the end of the nineteenth century[40]. Since then, several works have demonstrated that spacing retrieval has powerful effects on retention over substantial time periods, enhancing initial learning and slowing forgetting in several different situations[41-44](Figure 2). To summarize the main results, repeatedly rehearsing material in the same study session will not have abiding effects and may even impair learning. Conversely, retrieving the same material on different days and in different ways will produce long-term results. Moreover, as practice increases, the information will remain accessible through longer gaps and subsequent repetitions will take much less effort. Thus, once the information is acquired, it should be revisited with increasing intervals, starting with days and weeks, and then spreading out to months and, ideally, years[45](which is the idea behind spiral curricula).

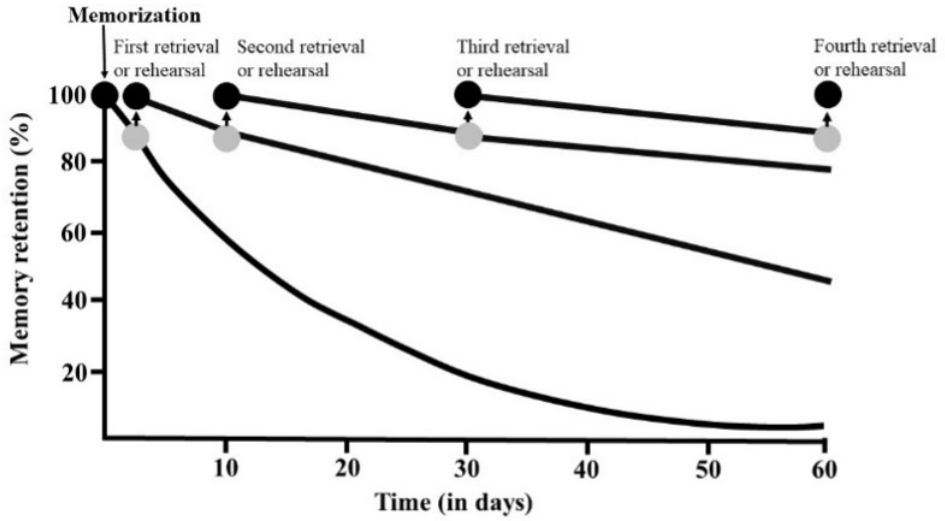


Figure 2. Idealization of the effect of spacing knowledge retrieval to slow and decrease forgetting. Modified from [40].

It is not the aim of this brief to discuss in depth different mechanisms proposed for memory consolidation and retrieval practice[46], but the effects of stress on learning due to different examination methods. However, all given data may be useful to capture the effects of stress due to examination, giving a broader context to this brief. As mentioned above, stressful events are common in educational settings, including exams, evaluations and deadlines, among others.

Effects of stress on memory and learning: the role of exams

If a situation is appraised as stressful, a well-described cascade of physiological and endocrine changes is set in motion in order to re-establish homoeostasis and to promote long-term well-being[47]. Although the stress response is very complex, with numerous mediators involved, two major stress systems appear to be critical for the modulation of learning and memory processes, the rapid autonomic nervous system and the slower hypothalamus–pituitary–adrenal axis. Within seconds, the autonomic nervous system is activated, leading to the release of catecholamines such as noradrenaline, both from the adrenal medulla and the locus coeruleus in the brain[47]. Catecholamines prepare the body for "fight-or-flight" responses and rapidly affect neural functioning in several brain regions critical for learning and memory, such as the hippocampus, amygdala and prefrontal cortex[48,49].

A second system is also activated in response to stress, the hypothalamus–pituitary–adrenal axis, about 10 seconds later than the autonomic nervous system, resulting in the release of corticosteroids such as cortisol from the adrenal cortex[47] (the adrenal cortex comprises the outer layers of the adrenal glands, which are found above the kidneys). In this context, it has been shown that glucocorticoids such as cortisol can induce memory enhancement or conversely impair memory function, depending largely on the temporal proximity between the stressful event and the memory process investigated[50,51]. For instance, stress experienced just before memory retrieval, when catecholamine levels are still high and cortisol levels are not yet elevated, may have very different effects from stress experienced 90 min before retrieval, when catecholamine levels have returned to baseline and cortisol actions are at work[51-54]. In this regard, declarative memory, i.e. the memory for facts, events and word meaning, which is the most studied type of memory on which glucocorticoids exert an influence, may be both positively affected through consolidation and negatively affected through impairment by cortisol. These contradictory effects may depend on the cortisol receptor type, dose, time of exposure, memory component and the salience of stimuli, retrieval being generally affected and storage being facilitated, especially for emotionally relevant events. Interestingly, glucocorticoids also induce hippocampal atrophy, specially under acute chronic stress conditions, which may impair long-term memory storage.

Similarly, distinct memory stages such as encoding, consolidation or retrieval may be differently affected by these time-dependent physiological changes after a stressful encounter, also in anticipation of a stressful encounter [51,55]. In this respect, it has been shown that exposure to mild or moderate punctual stress (see discussion below on the ambiguity of the word *stress*)

may result in better memory performance during the consolidation phase but conversely reduces memory performance during retrieval, which it is important to note is the case during most examinations. Acute stressors impair both consolidation as well as retrieval. These memory-enhancing and memory-impairing effects are strongly related to stress-induced cortisol and sympathetic activity[55].

The word stress may be, somewhat, ambiguous. One way to reduced ambiguity is by classifying stress in three categories, namely good stress, tolerable stress, and toxic stress[56]. "Good stress" refers to the experience of rising to a challenge, taking a risk, and feeling rewarded by an often-positive outcome. Even adverse outcomes can function as growth experiences for individuals with healthy self-esteem and good impulse control and decision-making capability, which are part of the so-called executive functions. "Tolerable stress", in turn, refers to situations where negative events occur, but the individual with healthy brain architecture is able to cope, often with the aid of family, friends, and other individuals who provide support. Finally, "toxic stress" refers to situations in which negative events, adversity or traumas are experienced by an individual who usually has limited support and may also have brain architecture that reflects the effects of adverse early life events that have impaired the development of impulse control and adequate self-esteem[57]. In other words, good or even tolerable stressors generating mild to moderate punctual stress may contribute to memory consolidation during the consolidation phase but may reduce memory performance during retrieval, and toxic (acute) stress impairs both processes, which it is worth noting during most examinations.

Despite this general information, it is also worth noting the existence of individual differences in temperamental characteristics which are relevant for the onset of stress in early childhood and adolescence[1,58,59]. Thus, for example, the presentation of more shy-inhibited behaviours such as fearful withdrawal from unfamiliar people, displays of shyness, etcetera, and associated behavioural inhibition, i.e., withdrawal and fear in novel and/or unfamiliar situations, are consistently related to more severe anxiety in later childhood, particularly social anxiety[60,61]. Associations between shy-inhibited temperament and later internalizing behaviours have also been established[59,62]. Similarly, it has been suggested that negative reactivity characteristics such as anger, distress at limitations, moodiness or irritability, during toddlerhood are strongly associated with the later development of broader internalizing behaviours and less so with later anxiety symptoms[63,64]. Moreover, individual resilient capacity to manage both anxiety and stress it is also crucial for interindividual differences, and in this way examinations may also be used to reinforcing this influential process allowing for positive adaptation in a context of significant adversity (resilience will be addressed in another brief).

Beyond the specific neural, physiological and molecular aspects of the effects of stress on learning and memory, what is most significant for this brief is the effect of stressful situations that may occur during examinations on learning and memory performance. Thus, it has been shown that stress at around the time of learning enhances memory, but stress long before learning or in a distinctly different context does not promote new learning and can even hinder successful encoding of new information[65] (Figure 3). For example, while moderate stress immediately before learning enhances later recognition memory, memory is impaired if stress was experienced between 1 hour and 30 min before learning[66-68]. At the molecular and cellular level, this impairment to learning has been associated with a decrease in neural excitability in the hippocampus long after cortisol release, as it has been shown in animal modelling[69]. Similarly, stress shortly after learning also improves memory consolidation, an effect which is more marked when emotionality is concomitant, thus highlighting the important influence of emotions on learning[55,70,71].

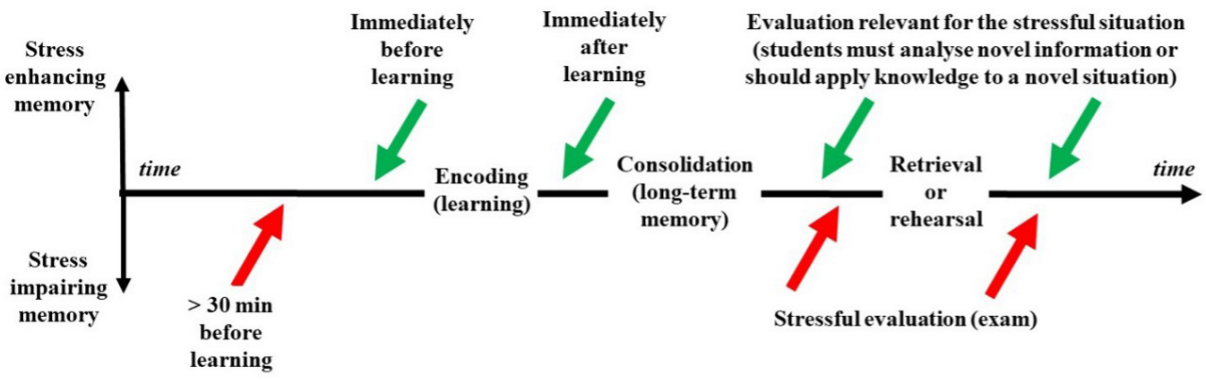


Figure 3. The effects of stress on memory, depending on temporal proximity and on specific memory process. Modified from [51].

As stated above, the effects of stress on memory extend to memory retrieval, which includes exams. Many studies have demonstrated that acute stress (or toxic stress according to the distinction above) impairs memory retrieval after a stressful encounter[72-76]. Interestingly for the focus of this brief, this retrieval deficit after stress has been found both in adults and in children, highlighting the relevance of these findings for educational settings[73]. Moreover, disruptive effects of stress on retrieval are stronger in emotional contexts, for example, after psychosocial stress[77,78]. Psychosocial stress is the result of a cognitive appraisal of what is at stake and what can be done about it, and can be defined as an imbalance between demands placed on us and our ability to manage them. However, crucial to the issue addressed in this brief, if the retrieval test, i.e., the exam or evaluation, is relevant for the stressful situation or a context is used to memory retrieval, i.e. there is context serving as a retrieval cue, recall is spared from the damaging effects of stress[53,79]. It is worth noting that in this regard the "context" do no refer to context-dependent learning, but to transfer knowledge to a new contextual situation. This point emphasizes the importance of evaluation methods that do not disrupt previous learning but instead contribute to its growth and consolidation, such as when students must analyse novel information relevant to the examination and apply knowledge to a novel situation (Figure 3; see the annex for an example). From an educational point of view, this can be achieved more easily with some forms of examination than others, for example, by means of essays in written exams, open-book exams, take-home exams, oral examination, report writing, etcetera.

Integrating new information into existing memories is a key process in education, which often involves some disruption. Furthermore, there is evidence that consolidated memories return to a labile state when they are reactivated, as occurs during an examination, which requires the subsequent re-stabilization of those memories in a process called reconsolidation[52,80,81]. During reconsolidation, a process involving the hippocampus[52] and the prefrontal cortex[82], the reactivated memory can be weakened, strengthened or altered[52]. Several studies support the hypothesis that stress can affect memory reconsolidation and memory updating, but the specific conditions leading to either impairing or enhancing effects of stress on reconsolidation are still under investigation[83-85].

Regarding the quality of learning, experiments, mostly using rodents, indicate that under stress more rigid stimulus–response associations are learned rather than complex representations of the environment[86-88]. In this way, it has been suggested that stress can affect not only how much information is learned but may also have considerable consequences for the nature and flexibility of memories and goal-directed behaviours[51,]which are at the core of executive functions. Executive functions are a set of cognitive processes that are necessary for the cognitive control of behavior, i.e. selecting and successfully monitoring behaviors that facilitate the attainment of chosen goals, which in turn must be an essential component in the education systems.

Core executive functions such as working memory, inhibition and cognitive flexibility are integral to daily life and to goal-directed behaviours. A growing body of research has suggested that stress may also impair core executive functions, which are also crucial for learning as well as for goal-directed learning. For example, it has been reported that stress impairs working memory and cognitive flexibility[9,51], which are central to some other abilities and skills that are crucial in education, such as decision-making, planning and imagination[89], depending on how these functions mature during childhood and adolescence[10]. In this regard, it can be hypothesised that exams' type and the way they are perceived by students may play a critical role in contributing to the development of this relevant functions.

Conclusions

Assessment is inseparable from teaching practice and affects both the way students learn and the way teachers teach. In consequence, it has been considered that to improve learning, examination and evaluation have to be critically analised[90]. Beyond factual knowledge, to favour cognitive processes such as those involved in executive functions, exams must allow for the mobilization of cognitive processes such as comprehension, description, representation, resolution, reasoning, reflection and communication[91]. This includes strengthening the feedback character of the examination[92]. Moreover, stressful situations, which are quite common during examination as well as during exam preparation, may also affect the learning process and memory formation, disrupting some aspects of memory retrieval and consolidation. However, when examination is coupled to the acquisition of new learning and knowledge which are perceived as relevant for the stressful situation, for example, when learning and testing take place in the same context, recall is spared from the damaging effects of stress[53,79]and may contribute to consolidating memory and developing executive functions, making the process of learning more efficient.

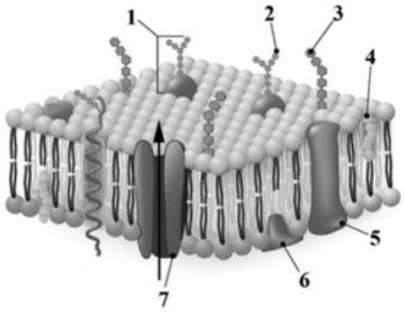
Taken together, data mentioned in this brief emphasize the importance of evaluation methods that do not disrupt previous learning, but instead, contribute to its growth and consolidation. Thus, from an educational point of view, methodologies used during examination have to be selected carefully to fulfil both the major roles of evaluations, that is, to serve as verification that a student is qualified and also as an educational tool to improve the learning process. To this end, novel approaches and both educational and scientific neuroscience research are needed to bring these ideas closer to the educational needs of each community, taking into account their resources.

Annex

Example of two distinct biology exams that use different methodologies. One of them (Example 1) is mostly focused on factual knowledge, while the other (Example 2) targets abilities and skills. They have been taken from the University Access Examination from different Autonomous Communities within Spain. Both are open access, and they were used in June/July 2020. Current educational policy in Spain allows decentralization of University Access Examinations, which are prepared by different tester teams. The author of this brief has been the coordinator of the biology examination for University Access in Catalonia for the last 14 years. Both examples are presented in their original version and language as well as translated into English. Despite there being no scientific studies on the effects on learning or memory of these two specific different methodologies, they can be speculatively deduced from general data given in this brief.

1. Conteste a las siguientes preguntas:
   a) ¿Cuándo se dice que un carbono es asimétrico? y ¿A qué da lugar la existencia de un carbono asimétrico? (0,7)
   b) ¿Cuáles son los carbonos asimétricos en la D-glucosa? ¿Cuál es el carbono que determina las configuraciones D y L cuando hay más de un carbono asimétrico? (0,6)
   c) Escriba y explique brevemente las principales funciones de los glúcidos. (0,7)

2. Observe la siguiente imagen:
   a) ¿Qué tipo de estructura representa? ¿Cuáles son sus funciones? (1,0)
   b) Nombre cada uno de los componentes señalados con un número. (0,5)
   c) Explique qué es la exocitosis y la endocitosis. (0,5)



Example 1. Written exam, short-answer questions designed mostly to evaluate factual knowledge. It also includes the interpretation of an image. Original language: Spanish.

English translation:

1. Answer the following questions:a) When is a carbon said to be asymmetric? And what gives rise to the existence of an asymmetric carbon? (0.7)

   b) What are the asymmetric carbons in a D-glucose molecule? Which carbon determines the D and L configurations when there is more than one asymmetric carbon? (0.6)

   c) Write and briefly explain the main functions of carbohydrates. (0.7)

2. Observe the following image:

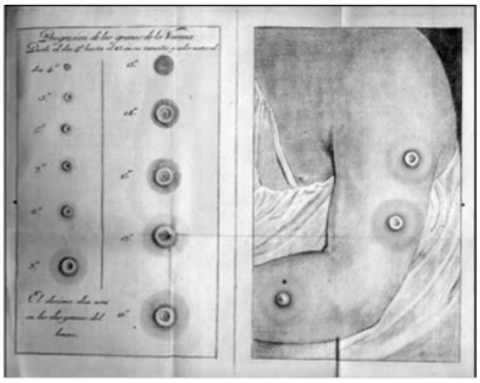
a) What type of structure does it represent? What are its functions? (1.0)

b) Name each of the components marked with a number. (0.5)

c) Explain what exocytosis and endocytosis are. (0.5)

Exercici 1

A principis del segle XIX, tots els intents de portar la vacuna de la verola a Amèrica havien fracassat. El viatge era massa llarg i arribava inservible. El metge Francesc Xavier Balmis va fer una proposta sorprenent: traslladar la vacuna inoculada en persones. El 30 de novembre de 1803 la corbeta *María Pita* va partir de la Corunya amb 22 nens procedents d'orfenats. Eren els «nens vacunífers» de la Reial Expedició Filantròpica de la Vacuna (1803-1806).



Làmines de Francesc Xavier Balmis en què es veuen les vesícules de pus produïdes per la vacuna.
FONT: *https://culturacientifica.com/2014/02/24/el-caso-de-los-ninos-vacuniferos.*

1. El procediment va consistir a anar inoculant esglaonadament la vacuna d'un nen a un altre fins al final del viatge. Al primer nen de la cadena li havia estat inoculat el contingut de les vesícules que desenvolupen les vaques que tenen la malaltia de la verola. Aquesta malaltia de les vaques, quan afectava els humans només ocasionava unes quantes vesícules. No feia perillar la vida i proporcionava protecció contra la verola humana.

Redacteu un text similar al del paràgraf anterior fent servir els cinc termes següents: *antígens, anticossos, immunització, virus de la verola de les vaques* i *virus de la verola humana.*

[1 punt]

2. Al cap de vuit dies de la inoculació del contingut de les vesícules, al primer nen vacunat li van aparèixer unes vesícules plenes de virus que van servir per a vacunar el nen següent, i així, successivament.

[1 punt]

a) En relació amb la resposta immunitària dels nens als quals s'injectava el líquid de les vesícules, completeu la taula següent:

Tipus d'immunització: activa ☐ / *passiva* ☐
Justificació:

b) En relació amb la procedència dels antígens, completeu la taula següent:

Tipus d'immunització: natural ☐ / *artificial* ☐
Justificació:

3. A l'hora de seleccionar els nens, Balmis va imposar la condició que no podien haver patit la verola ni haver estat vacunats prèviament. Des del punt de vista de la resposta immunitària primària o secundària, hauria funcionat la transmissió de la vacuna si no s'hagués complert aquesta condició en algun dels nens? Justifiqueu la resposta fent referència a aquests dos tipus de resposta immunitària.

[1 punt]

Example 2. Written exam, an essay question which provides novel information to students, designed mostly to evaluate abilities and skills and to take advantage of the stressful situation to consolidate learning (i.e., the context served as a retrieval cue and gives previously unknown information to students). Original language: Catalan.

English translation:

In the early nineteenth century, all attempts to bring the smallpox vaccine to America had failed. The trip was too long, and the smallpox vaccine arrived useless. A doctor, Francesc Xavier Balmis, made a surprising proposal: to transport the vaccine via inoculated people. On November 30, 1803, the corvette Maria Pita sailed from A Coruña [Galicia, Spain] with 22 children from orphanages. They were known as the "vaccinating children" of the Royal Philanthropic Expedition of the Vaccine (1803-1806).

Figure legend: Plates by Francesc Xavier Balmis, in which the pus vesicles produced by the vaccine can be seen. Source: https://culturacientifica.com/2014/02/24/el-caso-de-los-ninos-vacuniferos.

1. The procedure consisted of passing the vaccine from one child to another, step by step, until the end of the trip. The first child in the chain was inoculated with the content from the vesicles developed in cows that had the smallpox disease. This disease of cows, when it affects humans, only causes a few vesicles. It did not endanger life but provided protection against human smallpox.

Write a text similar to the one in the above paragraph using the following five terms: *antigens, antibodies, immunization, cowpox virus, and human smallpox virus*. [1 p]

2. Eight days after inoculation with the contents of the vesicles, the first vaccinated child developed vesicles full of the virus, which were then used to vaccinate the next child in the chain, and so on. [1 p]

a) In relation to the immune response of the children in whom the vesicles fluid was injected, complete the following table:

Type of immunization: active / passive

Justification

b) In relation to the origin of the antigens, complete the following table:

Type of immunization: natural / artificial

Justification:

3. When selecting the children, Balmis imposed the condition that they must not have suffered smallpox or previously been vaccinated. From the point of view of the primary or secondary immune response, would the transmission of the vaccine have worked if this condition had not been fulfilled by any of the children? Justify the answer by referring to these two types of immune response. [1 p]

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