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Insights From Neuroscience Into Foreign Language Teaching And Learning

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Abstract

The present article reports on specific findings of neuroscience research in relation to language teaching and learning. It states that among the evidence-based approaches, reading aloud, think-pair-share, and intensive training are qualified as important procedures in promoting learning. This is made possible as they intervene in shaping neural networks causing changes to specific structures of the brain in ways which foster memory encoding. A prominent role of the nature of the teaching environment is advocated. The significance of monitoring the stress levels in the classroom setting is highlighted. Discussion then turns to what is recently described as neuromyths in the domains of teaching and learning. The article finally concludes with the importance of scepticism in interpreting scientific knowledge in order to prevent introducing misleading educational approaches based on loosed scientific facts.

***Keywords**:* Evidence-based practices, Intensive training, Neuromyths, Neuroscience, Reading aloud, Teaching and learning, Think-pair share

1. Introduction

The precise cognitive mechanisms boosting the human drive to better succeed in foreign language teaching and learning are not entirely clear. The secrets are yet to be discovered. How can our understanding of the human brain informs us how to best learn what we intend

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to learn is a puzzling inquiry for which research is queen to assemble the mystifying pieces. Recent decades witnessed an utmost fortification of the techniques investigating this subject. Neuroscience research, most particularly, appeared to be a promising field that while unravelling the brain mechanisms could inspire challenging teaching and learning methods. Reporting on specific findings of neuroscience research is crucial towards bridging the gulf between traditionally remote disciplines and spreading out information that could well be transformed into better approaches to language teaching and learning. Indeed, Honga et al. (2017) argued that "[b]etter educational methods using research-based knowledge of the language centres of the brain...are essential for both language learners and educators" (p. 10).

It is evident that, for all beings, the cognitive function of learning is made possible through neural mechanisms. When it comes to language, however, learning aptitudes and outcomes are not the same through vertebrates and this is due to the fact that language has a different neurobiological basis across humans and nonhumans. Though it is argued that the presence of brain stem in all vertebrates indicates the presence of language (Alli, 2016), the language skills across these could not be the same due to the nonexistence of specific type of neural connections in animals which might "explain the unique ability of learning words in humans" (López-Barroso et al., 2013, p. 13168). One's cat could develop an understanding of specific human words but never could produce these words despite good understanding.

There exists an intricate relation between neural networks and language learning ability proper to mankind. The systematic functioning of the brain affects the learning procedures and learning affects the brain structuring and functioning as well. These internal mechanisms are subconsciously driven. Nevertheless, the dimension and nature of such structuring depends on internal as well as external factors intervening to define the scope of these. This

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refers us to the notion of neuroplasticity the principles of which could be the foundation of promising teaching strategies.

2. Neuroplasticity and the cognitive function of learning

Neuroplasticity is a key principle in the brain functioning and, thus, in all cognitive capabilities. It is defined as the property allowing the human brain to have the "extraordinary ability to functionally and physically change or reconfigure its structure in response to environmental stimulus, cognitive demand, or behavioral experience" (Li et al., 2014, p. 301). At the core of the neuroplasticity principle is the brain's internal activity and flexibility upon which the cognitive function of learning could be refined in presence of environmental stimuli provided, for instance, through specific goal oriented teaching procedures.

In fact, teaching procedures are the cornerstones of learning outcomes. It is admitted that "at their most fundamental and mechanistic level, teaching and learning are neurological phenomena arising from physical changes in brain cells" (Owens & Tanner, 2017, p. 1). As a matter of fact, learning takes place "through the modification of the brain's neural connections" (Herculano-Houzel, 2002, p. 102) where memory storing, encoding and retrieval have a great role to play in assuring the cognitive function of learning. Neuroscientists converge on the belief that the "basis of learning and memory creation lies in changes in electrically active nerve cells, called neurons, and the connections between them, the synapses" (Owens & Tanner, 2017, p.5).

The nervous system of all vertebrates is a "mosaic composed of hundreds to thousands of neuron subassemblies" (Williams & Herrup, 1988, p.424). During the synapse, "electrical signal is passed onto other neurons" usually through the release of the so called neurotransmitters carrying "the cellular signal" (Owens & Tanner, 2017, p. 3) encoding a specific type of information. There are different types of neurotransmitters "each with

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different possible effects" (Owens & Tanner, 2017, p. 3). In the language learning act, the release of specific types of neurotransmitters in the presence of particular stimuli is the chief creator of the learning orchestra the nature of which would define the learning outcome. Definitely, "neural connections in many different parts of the brain can change" in response to specific stimuli as such shaping new networks reflecting a synaptic plasticity that is "associated with and leads to behavioral learning and ...formation of memories" (Owens & Tanner, 2017, p. 3). This change over specific neural structures leading to volume modification of existing ones and the creation of new networks is what defines synaptic plasticity. The synaptic plasticity is found to be directly related to learning and memory (Takeuchi et al., 2014). Service (1992) reported that aspects of the working memory[1] are quite related to "learning new language material" (p. 21) as such affecting language proficiency. Among many factors, the way the linguistic information is stored, in reference to memory, "shapes [the] learning of second and foreign languages" (Jackson, 2016, p. 1). The way linguistic information is stored and retrieved could be a function of the synaptic plasticity.

Language is deeply rooted in the human brain and genuinely affected by the principle of neuroplasticiy. Identifying tasks with the potential to intensify the neural synapses in language-related regions should be beneficial to language learners. Recently, Honga et al. argued that the latest discoveries of "the language related brain areas by neuroscientists have added deeper understanding of language acquisition" (2017, p. 10). The most well-known language related brain regions are "Broca' s area, which is located in the left frontal lobe, and Wernicke's area, which is located in superior temporal lobe that is between the primary auditory cortex and the angular gyrus"(Honga et al., 2017, p. 10). Broca is related to

[1] Working memory "can be described as a limited amount of information that can be temporarily maintained in an accessible state, making it useful for many cognitive tasks" (Adams et al., 2018, p. 340)

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language production while Wernicke is rather related to language comprehension. In-between these two, there exists a wide set of neural connections not less important to the language function. Thus, it is estimated that teaching strategies ensuring the fortification of neural connections within these language areas should generate promising results.

Owens and Tanner (2017) stated that few of language teachers were "likely taught about the neurobiology of learning in [their] pedagogical training" despite the fact that teaching and learning are essentially "biological phenomena" (p .1) thus creating a gap in the teacher training programs. In the following, a set of potential helpful techniques are suggested in which the core benefit is reflected on the structure and volume of either gray[2] or white[3] matters, both constituting the central nervous system (Mercadante & Tadi, 2019). The following techniques which, as will be discussed, contribute to the release of neurotransmitters fortifying as such the neural synapses and fostering the learning process, are surely not new to the literature. Nonetheless, reporting them particularly with reference to their neuroanatomical effect could hopefully reinforce the rationale for their use in actual teaching strategies. This stems out from the belief that spreading out such knowledge to unveil the unseen side of teaching achievement proper to specific strategies will raise the awareness of teachers and further encourage educators to incorporate those strategies in their classrooms while keeping up faith in their potential effect.

3. Reading aloud technique

Gibson (2008) stated that "[t]o read aloud or not to read aloud seems to generate a lot of interest among EFL/ESL teachers around the world" (p. 29). In the literature of general

[2] Gray matter "makes up the outer most layer of the brain" (Mercadante & Tadi, 2019, para. 1). It surrounds the cereberum but is also found in inner parts of the brain called "nucleus" or "nuclei". Grey matter reflects "a high concentration of neuronal cell bodies". It "extends from the brain into the spinal cord" (Mercadante & Tadi, 2019, para. 2).

[3] White matter "contains a high concentration of myelin" (Mercadante & Tadi, 2019, para. 2) and constitutes an essential section of the brain and the spinal cord (Mercadante & Tadi, 2019)

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English language teaching methodology, reading aloud technique is not recommended and received critiques over the last decades (Gibson, 2008). Despite the set of objections to applying this technique in the language classroom, Gibson (2008) indicated that it has been proved that the benefits "could outweigh the disadvantages" if reading aloud is "used sensitively and with clear aims" (p. 30). Adopting a "careful and appropriate use of the activity", reading aloud could be "a useful learning tool" (Gibson, 2008, p. 30). In parallel to this assumption, there is growing recent evidence suggesting the efficiency of reading aloud in the promotion of different linguistic skills (Omar, 2016; Santoso, 2015). Beyond the debate over the use of this strategy in the research field of English language teaching, the neurobilogical basis of the reading aloud technique, as it will be discussed, adds to the credibility of the claimed efficiency in autonomous as well as interactive learning.

Let's first clarify the notion of the reading aloud technique. Omar (2016) explained that a reading aloud strategy could be initiated with the teacher reading aloud a story in the target foreign language and then engaging students to read the same story "sentence by sentence". Story reading is done "as a class, as a group and finally individually" (Omar, 2016, p. 23). The teacher considers correcting student's pronunciation during the reading sessions. He/she conducts "vocabulary work during [the] read-aloud sessions" while drilling "the difficult words" and instructing learners to "repeat the words a few times before providing the meanings of the words using pictures, illustrations in the book, actions and translation" (Omar, 2016, p. 23). The conduction of a rich and insightful discussion of the new vocabulary items could be using "illustrations, providing brief definitions, using synonyms and gestures, and using words in a sentence in a different context" (Omar, 2016, p. 20).

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Research proved that reading aloud contributes to vocabulary development and comprehension improvement (Brabham & Lynch-Brown, 2002; Omar, 2016; Whitehurst et al., 1994). Its role in promoting word recognition capacities was also highlighted (Stahl, 2003) which improves learners' linguistic skills in different respects. The importance of this strategy stems from its engaging learners as "active listeners" providing them with opportunities "to expand their vocabularies and broaden their understandings of the world around them" (Omar, 2016, p. 19). Storybook reading has been found to provide "a range of experiences on vocabulary acquisition in terms of involvement in conversations and exposure to new and sophisticated words" (Omar, 2016, p. 20). Research showed a significant effect of interactional reading aloud style (Brabham & Lynch-Brown, 2002) and indicated that "vocabulary instruction using text talk as a readaloud technique can be effective in teaching... rich and robust vocabulary words" (Omar, 2016, p. 20).

Actually, apart from vocabulary development, the technique could target different language skills. Researchers indicated that "effective read-aloud sessions can promote many types of skills and abilities...crucial in assisting children to learn the English language" (Omar, 2016, p. 17). Hence, reading aloud seems to constitute a promising technique in the language teaching domain. The essence of the claimed importance of the reading aloud technique is its acting on specific neural connections argued to play an important role in language learning in so different respects. Although reading aloud is usually discussed as an interactive strategy to be held between teachers and students, its neural basis indicates an effect that transcends this description as it widens the potential effectiveness to encompass a self interactive strategy in which the learner reads aloud to interact with his own mind as such fostering autonomous learning. Thus, the effectiveness of the discussed strategy is not limited to interactive storybook reading within an interactive teaching approach necessitating two parties; a teacher and a learner.

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Much of the effectiveness of the strategy lies on the experience in which the learner reads aloud the exact linguistic unit s/he hopes to understand or to memorise. The mechanical force producing the motor act of reading aloud a word, a phrase or a sentence is transformed instantly to an electrical signal allowing the hearing (Stöver & Diensthuber, 2011) of the just uttered linguistic form. Hearing one's own readings in real time activates specific roots of knowledge upon which lies the desired effect of the read aloud technique.

Study finds that word learning is mediated through the bundle of nerve fibres connecting the traditionally described language centers Broca and Wernicke (López-Barroso et al., 2013). This bundle of nerve fibers is called arcuate fasiculus and refers to a white matter tract known to be implicated in the language functions (Eichert et al., 2019). López-Barroso et al., (2013) found that "performance in word learning correlates with microstructural properties and strength of functional connectivity of the direct connections between Broca's and Wernicke's territories in the left hemisphere" (p. 13168). It is suggested that human aptitude "to learn new words relies on an efficient and fast communication between temporal and frontal areas" (López-Barroso et al., 2013, p. 13168), and thus on the specific structure of the arcuate fasciculus. This neural connection ensured by the arcuate fasciculus is very crucial to ensure the language production act (Eichert et al., 2019).

Yeatman et al. (2011) observed the role of the arcuate fasciculus in the development of reading skills. Study finds that learning to read improves the structure of this tract (Thiebaut de Schotten et al. 2012). An important step in the learning to read act is the ability to discern phonemes. Indeed, Saygin et al., (2013) found that the integrity and volume of the left arcuate fasciculus correlated with strong phonological awareness. Thus, tasks aiming at raising the phonological awareness could enhance the reading ability as such improving the structure of the arcuate fascilus which will hopefully improve the cognitive basis for learning new words.

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Indeed, Robertsson et al. (2016) reported a significant correlation between the anatomy of the posterior segment of the arcuate fasciculus (AF) and vocabulary comprehension and reading performance. "Auditory and motor areas communicate directly through the AF" (López-Barroso et al, 2013, p 13168). The arcuate fasiculus perceived as a "possible anatomical substrate of auditory-motor integration" could indeed "represent a key step for language development" (López-Barroso et al, 2013, p. 13171). Tasks leading to the fortification of the arcuate fasciculus entails enhancing the connection between auditory and motor cortices and thus between temporal and frontal areas which seemed to be activated while exercising reading aloud.

Based on the above scientific reports, one could assume that in a vocabulary task, for instance, instructing students to read aloud the words would fortify the cognitive roots to memorise them since that would mean activating both motor and auditory cortices simultaneously. One could suggest that this method would, hopefully, generate positive effects on different language tasks while inducing the strengthening of the arcuate fasciculus.

Thus, the reading aloud technique would help the learners better learn what they intend to learn in the context of autonomous learning as suggested by Gibson (2008). The technique could also be wisely incorporated in the language classroom as well. In a vocabulary class, the teacher could prepare a suitable setting for this "speaking aloud" technique through providing students with headsets. Otherwise, the task could be organised in ways requiring students to simultaneously speak aloud rehearsing the intended word or phrase. This is open to the teachers' creativity in response to the nature of the target linguistic information and learners' needs. The essential goal is to fortify both "structural" and "functional...measures of connectivity between temporal and frontal language territories in the left hemisphere" which

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is found to "predict word learning abilities" (López-Barroso et al, 2013, 13170). This could be made possible through reading aloud strategy as reflected by its anatomical basis.

The suggestion of incorporating the reading aloud strategy on the basis of what neuroscience suggests in this subject is not detached from reality. It is well found to be beneficial for the language learner in so different respects relating to most of the language skills. Santoso (2015) proved that an interactive reading aloud approach could improve teaching and reading comprehension. The study revealed that students' reading comprehension activities are found to be ameliorated "in four areas, i.e. test results, meaning construction, motivation, and word definition" (Santoso, 2015, p. 10-11). "[I]nteractive read-aloud is effective in supporting comprehension and vocabulary development" (Santoso, 2015, p.11). In addition, the reading aloud technique is found to "help reading by reinforcing graphemic-phonemic correspondences" and "aid the acquisition of prosodic features of English" as well as to "develop writing skills by using it as oral proofreading" (Gibson, 2008, p. 29). Besides, Gibson suggested that the technique may "help some anxious students to feel more able to speak" (2008, p. 29). Thus, what anatomically leads to improving the reading skill goes actually through a process leading to the mastery of other skills building up a successful sequence the key of which is strengthening the connections between the auditory and motor cortices made possible through the reading aloud technique. It is important to understand the anatomic basis of this technique in order to better grasp its scope and significance.

For all what preceded, the role of reading aloud "in language learning should now be reappraised" (Gibson, 2008, p. 29) and wisely incorporated in the language classroom. In the following, the effectiveness of another teaching strategy is discussed with reference to its anatomical effect.

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4. Think-pair-share technique

Think Pair Share is a "cooperative learning discussion strategy first developed at University of Maryland in 1981 and adopted by many writers in the field of cooperative learning since then" (Sahrin & Bugis, 2003). While engaged in this sort of activities, students are invited to "*think* individually about a solution to a problem", "*pair* with a neighbor to discuss their ideas", and finally "*share* their thoughts with a larger group" (Owens & Tanner, 2017, p. 2). The benefits of such type of activities is reported, for instance, in improving aspects related to the reading aptitude (Carss, 2007; Sapsuha & Bugis, 2013) as well as oral communication skills (Carss, 2007; Lyman, 1981; Usman, 2015). More recently, its efficiency in promoting students' learning motivation and achievement are reported (Hetika et al., 2017).

It is "a consensus among neuroscientists" that learning and memory formation depends on changes in neurons and synapses (Owens and Tanner, 2017, p. 2). It goes without saying that memory is a foundation stone of any language learning task. A good teaching approach should induce the fortifications of synapses in order to strengthen memory encoding of any sort of language event or information. In this concern, analysing the neurobiology of think pair share, Owens and Tanner (2017) came to the conclusion that in this think pair share activity "all of the phases ... are in service to... encoding memory in synaptic connections and neural circuits" (p. 2). The cognitive mechanisms underlying this type of activity are found to cause "the connections between nerve cells inside the students' brains to be changed for a long time, allowing them to recall the solution to the task months later and perhaps for the rest of their lives" (p.2). The effect on memory encoding this activity seems to bring about is important for language learning. More specifically, the suggested long term effect constitutes a crucial component to reach a good level of language proficiency.

In particular, the nature of think pair share technique provokes active learning to take place. No matter what the learners' attitudes or learning habits are, they are all invited to

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interact and share thoughts. Presenting their thoughts regarding the optimal answers to the required task, they are naturally driven to defend theirs and spontaneously forced to be actively engaged. It is a validated educational finding that "[a]ctive forms of studying improve test performance over passive forms" (Owens & Tanners, 2017, p. 5). Indeed, from "passive exposure to knowledge" (Owens & Tanners, 2017, p. 5) to an active, self engaging technique, this type of activity puts the learners at the core of the language task (Owens & Tanners, 2017). This is deemed important in any learning process and language learning included.

Extrinsic factors shaping the language learning environment are important as they affect and shape intrinsic values proper to the learner's mind set. The extent to which the learner is active during language learning, aware of the learning act as well as the required cognitive strategies necessary to succeed this act, brings about levels of self-control which directly relates to the notion of metacognition and thus, to metacognition processes. Stated simply, metacognition could be defined as "thinking about thinking" (Livingston, 2003, p. 3). Metacognitive knowledge is "knowledge that can be used to control cognitive processes" (Livingston, 2003, p. 3) which is described to play a crucial role in the cognitive function of learning (Livingston, 2003). In actual fact, the cognitive dimensions of metacognition is found to "enabl[e] us to be successful learners" (Livingston, 2003, p. 2).

Interestingly, research reports a positive effect of think-pair share strategy on students' metacognition (Carss, 2007). Carss found that the strategies of think pair share afford students with "a vehicle to link existing knowledge with new knowledge, both from texts read and from listening to their partners" and that sharing their thoughts with a partner enables them to "trial these new ideas and ... clarify or rearrange them before presenting them to the larger group" (2007, p. 102). Reporting Students' attitudes regarding the benefits of using think-pair share in their language classrooms, Carss mentioned their qualifying the technique as helpful

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and efficient as it helps them " 'understand better' and create a clearer picture in their mind" (2007, p. 102). The strategy "helped them to share and compare main ideas so they were able to then explain these to the group more effectively" (Carss, 2007, p. 102). This actually confirms the suggested "link between language and thought" indicating "increased metacognitive awareness facilitated by the use of the TPS[4] strategies" (p. 102). For more successful learning, students should be instructed and involved in tasks allowing them to "be more aware of their learning processes and products as well as how to regulate those processes" (Livingston, 2003, p. 5). Claiming that promoting these cognitive strategies through metacognitive experiences instructed to learners plays a great role in the learning process (Livingston, 2003) should not be surprising since, neurologically speaking, it relates to reinforcing the synapses in regions supporting memory encoding and retrieval and thus, fostering learning. This inspires language teaching methods based on this type of cooperative learning and invites language teachers to wisely incorporate think pair share in their classrooms.

In the following, focus shifts to the need for adopting intensive training of the linguistic skills to reach language proficiency. The necessity to adapt the teaching schedule to encompass required training is discussed in view of the importance of reaching foreign language proficiency for learners.

5. An intensive training based approach

That training the mind is important is not new to the teaching pedagogy. The outcome of training is always taken as a proof of efficiency in the learning act. But, what if we dig deeper in to the unseen anatomical effect of training; wouldn't that change teachers' perspective on the scope of the use of training as a pedagogical act? Wouldn't training become a principle in all tasks rather than a ranked technique for a set of particular tasks qualified as difficult?

[4] Think Pair Share

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It is a scientific fact that "[d]eliberate practice is important for gaining expertise" since based on the neuroscientific knowledge of the fact that synaptic plasticity is "specific to the particular neurons that are active together" as such reflecting the crucial role of "frequent" and "active" cognitive exercise (Owens & Tanner, 2017, p. 5). This indicates the importance of well instructed and goal oriented intensive training of the target neural systems in the brain directly related to the cognitive function of language.

The idea of intensive training based approach transcends the notion of the limited training of what is thought to be intricate since the notion of intricacy itself does not read the same across students with, naturally, different aptitudes. In order for information to be retrieved at demand it should be well incorporated in the long-term memory. "Long-term memory is made of declarative and procedural knowledge: the former is the knowledge about facts and the latter is the knowledge about how to perform tasks" (Sanatullova-Allison, 2014, p. 2). Fortifying its neural substrates is crucial towards succeeding the learning experience. Definitely, this could be made possible through intensive training. Dragansky et al. (2004) found that training induces gray matter changes in the human brain. Interestingly, density of grey matter is found to be quite related to foreign language proficiency (Mechelli et al., 2004). Research finds that an increase in the level of foreign language proficiency correlated with the density of the gray matter (Stein et al., 2012). Thus, regardless of the nature of the target linguistic information, its successful encoding could be a function of how many times the information was encountered and highlighted. In any language related task, information should be mediated through an intensive training to ensure better chances for different language aspects to be memorised not only in the short memory but in the long one. Training would help the learner better discern specific information within the melting pot the teacher is filling in.

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In Tunisia, practically, the idea that a better ground for foreign language proficiency necessitates an intensive training of different language skills contrasts with the limited number of scheduled hours for the language subject in both secondary and primary education. In spite of the fact that foreign language mastery is reported to be directly related to general academic achievement (NEA research, 2007), the Tunisian education system has not yet been aware of this equation. Let's take a step back and define the notion of academic achievement as "the outcome of education" and more specifically, "the extent to which a student, teacher or institute has achieved their educational goals as reflected in the percentage of marks scored by the student in the university exam of any programme" (Kumar, 2014, p.1). The ultimate goal of learners is to visualise their knowledge through the maximum possible scores upon which success would be decided. Academic success has been found to be "a function of several variables" among these is "proficiency in language of instruction" (Kumar, 2014, p. 2). In Tunisia, the French language is the language of instruction in scientific subjects for secondary school students. However, it seems that the core benefits of a second language are not only related to whether it is the language of instruction or not.

According to the benefits of second language study (NEA Research, 2007), research finds that learning a second language "benefits academic progress in other subjects" (p.2), "narrows achievement gaps" (p.3), "benefits basic skills development" (p.3), "benefits higher order, abstract and creative thinking" (p.4), "enhances a student's sense of achievement" (p.4), "enriches and enhances cognitive development" (p.4), "improves chances of college acceptance, achievement and attainment" (p.6), and finally "enhances career opportunities" (p.6). Therefore, reaching second language proficiency could positively impact students' wider academic outcomes. It is high time for Tunisian decision makers to consider increasing language teaching hours allowing the desired training of language related cognitive skills to reach an utmost fortification. Training the mind in using foreign language skills helps to

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establish an unconscious recall, use and appliance of the skills at demand in authentic situations. With no intensive training of language skills, a good mastery of language skills would be almost difficult to achieve.

6. Recent evidence-based beneficial practices: minding the nature of the learning environment

In September 2019, the international report of Betts et al. (2019) stated several examples of evidence-based practices in teaching. These are the following:

> "Emotions can affect human cognitive processes, including attention, learning and memory, reasoning, and problem-solving", "Explaining the purpose of a learning activity helps engage students in that activity". "Maintaining a positive atmosphere in the classroom helps promote learning". "Stress can impair the ability of the brain to encode and recall memories". "Meaningful feedback accelerates learning" (p.8)

These evidence-based practices are strongly supported by scientific research (Betts et al., 2019). Thus, these for instance could well be the basis for the foundation of scrutinized innovative methods in the teaching sphere where the starting point would be the teacher's outlook, attitude and manner inside the classroom. Specifically, minding the thread of positive emotions in the classroom allows positive psychology to dwell and reduce the stress.

Stress hormones are susceptible to the inhibition of the learning procedures (Lupien & McEwen, 1997). Aiming to reduce the stress itself necessitates innovative methods that teachers should incorporate in their teaching style including particular punishment strategies following undesired behaviour with the less stressful effect but the most desired outcome. While research on this subject has yet more to say, it seems self evident that punishment techniques should mind the students' dignity as a crucial part in maintaining positive attitude in the classroom. Research finds that stressful events could lead to the onset of depression episodes and are actually the most predicting factors of the latter (Slavich & Irwin, 2014).

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Obviously, students are not immune counter this psychological threat in the classroom. Being always enclosed in a stressful learning setting could negatively affect their outcomes, and thereafter, their self-esteem.

Agroskin et al. (2014) found that "[p]ersons with low self-esteem had reduced levels of regional grey matter volume in structures known to play a role in emotional self-regulation in response to threatening and stressful experiences". By analogy, this reduced grey matter could affect language learning aptitude since it is argued that increase in grey matter density correlates with foreign language proficiency (Stein et al., 2012). Thus, it is the responsibility of teachers to reduce the stress levels in their teaching environment and promote a high self esteem attitude for their students. This is critical towards preparing the suitable ground for efficient learning to take place. It is a neuroscientific principle that specific chemichals (e.g. cortisol) "released during stress, depresses synaptic plasticity" and thus, inhibits learning procedure since memories, crucial to the learning act "are encoded as synaptic networks" (Owens & Tanner, 2017, p.5). A teaching environment with low stress levels and high self esteem components would certainly induce motivation and attention both described as factors for dopamine[5] release as such enhancing synaptic plasticity (Owens & Tanner, 2017). Studying the organisation and possible functions of neurotransmitters, Everitt and Robbins (1997) noted how the release of specific types of chemicals under specific circumstances like attention increase would promote the cognitive function of learning. It is less likely for students to discern the value of paying attention in a stressful and unmotivated setting. Without a good learning environment, learning would be inhibited and the claimed efficiency of any learning strategy would most probably evaporate.

[5] Dopamine is a type of neurotransmitter which is related to feeling pleasure

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In point of fact, recent decades witnessed a specific enthusiastic attitude towards applying the knowledge of brain science to learning and teaching approaches. However, interpretation of scientific knowledge is not an easy task and caution is warranted. Brain science findings are not generally accessible to the general public and surely necessitate specific background to deal with it. Enthusiasm alone in the part of educators could be misleading. There is good reason, therefore, to consider clarifying some of the most known publically shared misconceptions about teaching and learning.

7. Misconceptions about the relation between learning/teaching and brain

Clarifying the set of the widely received misconceptions would help teachers and learners, keen to benefit from available neuroscience knowledge, be more aware of scientific reality vs. public misconceptions. Importantly, that would also raise the awareness of the interested public about neuromyths and reduce the scope of erroneous application of neuroscience.

In the following, the three most prevalent neuromyths in the education field are presented with reference to the work of Masson and Sarrasin (2015). The first received myth is about the effectiveness of adapting innovative teaching methods in response to different students' learning styles. It is argued that students differ on which style they prefer to receive information since there are different information transmission methods (Buckley et al. 2016). For instance, a learning style could be "auditory", "visual", or "kinaesthetic" (Betts et al., 2019, p. 8). The myth suggests that teachers ought to adapt their teaching strategies to students' preferred learning styles for better learning results. Studies, however, found little

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evidence to sustain this pedagogical thread (Masson & Sarrasin, 2015). Despite the strategy seems appealing and promising at face value, it has no scientific solid basis (Masson & Sarrasin, 2015). Acknowledging the differences between students is a different story and is surely good when it helps the teacher be aware of the difficulties some learners may be facing in the classroom setting. This allows teachers to create more flexible and comprehensive attitude with their students which would certainly benefit the teaching environment and thus foster the learning process. What is described as a myth is the fact to believe that providing the student with a style of teaching matching his/her particular style of learning will definitely ameliorate his/her success rate (Masson and Sarrasin, 2015).

With an average prevalence of 80% among teachers, research described a second widely received neuromyth in the teaching domain (Masson & Sarrasin, 2015). The neuromyth concerns the effect of hemispheric dominance on students' output (Masson & Sarrasin, 2015). Research finds that there are actual differences between the two hemispheres (Olfaz, 2011). The right brain is described as "better at copying of designs, discrimination of shapes, understanding geometric properties, reading faces, music, global holistic processing, understanding metaphors, expressing emotions and reading emotions", while the left brain is described as "better at language skills, skilled movement and analytical time sequence processing" (Olfaz, 2011, p. 1508). Although "a considerable number of cognitive functions have been found to be lateralized" (Ehert, 2006, p. 54), the fact to explain individual differences among learners on the basis of differences in hemispheric dominance is not strongly supported in the literature (Masson & Sarrasin, 2015). This misconception could have far reaching negative implications.

Let's take the example of students described with a dominant right brain. The fact that the left side of the brain is described as logical and analytical does not necessarily entail those

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right sided students should have low scores in mathematics compared to the left brain sided ones. In normal conditions, students have good chances to excel in any subject regardless of their hemispheric dominance. Considering the opposite to be a fact beyond doubt would affect students' self esteem and inhibit their learning processes in specific subjects perceived as not belonging to their 'brain strength zone'. Excelling at relatively 'difficult' areas could be possible thanks to the synaptic plasticity whereby, under specific circumstances, underactivated regions reflecting power performance in x subject could develop and change. Increasing neural activation of these regions could rewire the structuring of the brain and strengthen the bond between neural networks as well as create new ones boosting further the brain's aptitudes. Owens and Tanners (2017) argued that "[s]tereotype threat undermines learning and performance" (p. 5) which calls for the necessity of defying all educational stereotypes. In the absence of sufficient data teachers should not consider efficient to adapt teaching techniques on the basis of learners' hemispheric dominance until this is scientifically proved. For the time being, teachers as well as learners should be aware that there is no solid basis for such claims.

In addition to the above mentioned neuromyths, Masson and Sarrasin (2015) admitted that the third most received one concerns the benefits of coordination exercises on the integration of left and right hemispheres. Coordination exercises are claimed to be as efficient as to improve cognitive functioning in the learning tasks. One example of these exercises is for instance using your right hand to touch your left ankle (Masson & Sarrasin, 2015). One of the most known programs offering trainings based on coordination exercises and receiving attention at an international level is the popular Brain Gym program. Despite the wide popularity of this program, no credible empirical studies are reported to support neither its theoretical basis nor its claimed beneficial effect (Hyatt, 2007). Its underlying principle has been constantly invalidated by empirical research studies (Spaulding et al., 2010).

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Summing up the stated misconceptions, Masson and Sarrasin argued that

> "a couple of years ago, the notion of learning styles, the idea of hemispheric dominance, and the belief that coordination exercises can improve learning were not considered neuromyths. Today, however, these ideas are known to be false. It is therefore time to turn to more effective teaching methods that are better adapted to the brain function of students, and to give up these neuromyths that place students in restrictive categories (such as visual learner or right-brained, etc.) that, in addition to being unfounded, can bias the way students perceive themselves as learners" (2015, p. 31)

Nonetheless, strictly criticizing the above stated misconceptions does not firmly entail those have no minor possible effect on the teaching/learning procedures. The effect, however, is not as significant as to inform and orient educational pedagogies. Ongoing research on neuromyths is probably about to bring a consensus about the subject. More recently, in September 2019, the international report on neuromyths and evidence-based practices in higher education concluded that neuromyths to which respondents from different countries were most susceptible included:

- "Listening to classical music increases reasoning ability",
- "A primary indicator of dyslexia is seeing letters backwards".
- "Individuals learn better when they receive information in their preferred learning styles (e.g., auditory, visual, kinesthetic).
- Some of us are "left-brained" and some are "right-brained" due to hemispheric dominance, and this helps explain differences in how we learn".
- "We only use 10% of our brain". (Betts et al., 2019, p. 8).

Future research may support or further refute the actual popular claims. Until strong scientific evidence is provided, educators should not be contented with teaching methods based on loosely supported facts. It is the researchers' task to clarify the picture while

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scrutinizing what is usually beneficial reflecting a fact and what it occasionally beneficial reflecting a myth sometimes supported by personal, non-scientific, testimonies. Neuromyths "are loosely based on scientific facts" thus, "they may have adverse effects on educational practice" Dekker et al. (2012, p. 1). This should trigger serious research to be done in order to raise awareness of educators. Good intentions fused with misinterpretations of science could distort the thread of confidence between educators and learners. Over and above, education is a science and should never be a place for enthusiastic outbursts.

8. Conclusion

This article is a modest attempt to cast light on specific neuroscience discoveries that could inform better learning and teaching habits. Certainly, the reported scientific facts should be subject to more rigorous investigation and experimentation to be either supported or criticised. In general, scepticism is required to distinguish between pseudoscience and science (Dekker et al., 2012, p. 6) as these tend to be sometimes confused. Research finds that "possessing greater general knowledge about the brain does not appear to protect teachers from believing in neuromyths" (Dekker et al., 2012, p. 6). This demonstrates the need for "enhanced interdisciplinary communication to reduce such misunderstandings in the future and establish a successful collaboration between neuroscience and education" (Dekker et al., 2012, p. 6).

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