Fifty Years of Second Language Acquisition Research: Critical Commentary and Proposal

П'ятдесят років досліджень у галузі вивчення другої мови: Критичні коментарі та пропозиції

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ABSTRACT

Introduction. The article evaluates contemporary research on psycholinguistics and neurolinguistics to find answers related to why child first language (L1) acquisition relies on different processing methods compared to adult second language (L2) acquisition, and why an L2 can be complex for adults to learn. This paper is basically a critical appraisal of language acquisition (LA) research proposing new venues to explore.

Aims. The primary goals of this article are to emphasize the need for treating the brain as a testable scientific hypothesis, rather than merely a philosophical theory and to illustrate the need to integrate L2, brain, mind and the learner at every moment to account for LA.
Method and Results. To achieve these intriguing goals, previous research on psycholinguistics and neurolinguistics is critically reviewed. The review has shown that the brain in SLA research has been treated simply as a philosophical theory. This, in my view, has serious impacts on the progress and development of the field in two ways:

a. It causes the research to be held back by assumptions that have hardened into dogmas and act against open-minded thinking.

b. It leads researchers to depend solely on learners’ performances (the actual use of language) to describe and explain the nature of the linguistic systems that L2 learners develop (competence) and to explain how an L2 is acquired. However, we all know that performance is not on all occasions a perfect reflection of competence (cf. Chomsky, 1965, 1988)

These two points emphasize the need for treating the brain as a testable scientific hypothesis rather than merely a philosophical theory and exemplify the necessity of continuously integrating second language (L2), brain, mind, and the learner at every moment to explain both why learning occurs and why it fails to occur.

Conclusions. The paper offers a critical appraisal of previous research into psycholinguistics and neurolinguistics. It argues that the brain in second language acquisition (SLA/L2A) research has been treated merely as a philosophical theory for a long time, resulting in findings that lack actual neurolinguistic analysis. The paper suggests that theoretical explanations for why children acquire L1 faster and more easily than adults acquiring L2 align with recent testing of the brain, revealing differences in brain activity waves between early and middle childhood compared to adulthood. This indicates distinctions in language acquisition between children and adults in terms of brain wave activity, size of grey matter, and other factors.

Key words: second language acquisition/learning; adult L2 learner; brain/mind; contemporary research into SLA; future research into SLA.

Introduction

The difference in outcome between the child first language (L1) and adult second language (L2) cases, as Schachter (1996) puts it, is ‘strong and unambiguous’ (168). The outcome of L1 acquisition (FLA/L1A) is complete success; all normal children invariably acquire successfully to normal, native-like levels the target language(s) they are exposed to (cf. Anderson & Lightfoot, 2002; Chomsky, 1957, 1965, 1981; Fitch, Hauser & Chomsky, 2005; Lenneberg, 1967; Lightfoot, 1999; Pinker, 1995). In contrast, adult L2A results in varying degrees of partial success; the overwhelming majority of adult L2 learners
never achieve native-like mastery of the target language.* This prevailing view of the L2 ultimate attainment (the end-state mental representation of language), which indicates that complete success is rare (if not impossible) in post-adolescent L2A, is revealed in the following quotations:**

“The ultimate attainment of most, if not all, of adult L2 learners is a state of incompleteness with regard to the grammar of the L2” (Schachter, 1996: 160).

“With few exceptions adult learners fail, often miserably, to become indistinguishable from members of the ambient L2 speech community” (Eubank & Gregg, 1999: 77).

“For most adult learners, acquisition stop[s] – “fossilizes” – before the learner has achieved native-like mastery of the target language” (Lightbown, 2000: 179, as cited in Han, 2004: 4).

“Native-like performance is the exception rather than the rule” (White, 2003: 263).

This contrast in ultimate attainment – full success among L1 acquirers vs. lack of full success among L2 learners – begs an important question: why complete acquisition is possible in L1A, whereas it is impossible in L2A. Chomsky (1957, and much of his subsequent work) proposes a plausible answer to this question, which is that children come to the task of language acquisition (LA) with prior linguistic knowledge as part of genetic endowment that guides them in the course of acquiring their native language***. However, it is believed that “there is a limited developmental period during which it is possible to acquire

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* Selinker (1972) suggests that the complete success rate in an L2 is 5 percent of learners. Over the years, this success rate proposed by Selinker (1972) has been widely quoted (for more details, refer to Birdsong, 1999; Han, 2004).

** For detailed discussion about ultimate attainment in L2A (also referred to in the literature as the steady state, or the final state), see among many others Birdsong (2001, 2004), Gregg (1996), Johnson and Newport (1989), Long (1990, 2003), Selinker (1972, 1992) and Sorace (2003); or for a review of the literature that addresses this issue, see Han (2004), and White (2003).

a language, be it L1 or L2, to normal, native-like levels” (Birdsong 1999: 1). This view that a critical period characterises LA is referred to in the literature as the critical period hypothesis (CPH). This hypothesis states that the ability to acquire a language with native-like competence is related to the initial age of exposure, meaning that learners who begin the process of second language learning (SLL) after passing the critical period – after a certain age – are not expected to attain native-like levels of competence (native underlying knowledge of language) at the end state. This obviously raises an important question: why is L2 learning affected by late exposure to a language? To put it another way, what makes the brain at a certain age lose its innate (biological) ability that is supposed to guide the process of LA? A widely accepted answer to this question comes from the biological notions of brain maturation and plasticity. The view that there is a critical period that characterises LA was a theory in neurolinguistics; it assumes that the brain is plastic only at an early age of development, and therefore, it can modify its own structure, organisation and function as a direct consequence of experience and learning. As a result of this developmental plasticity, the brain can develop and begin to specialise; specific brain functions become increasingly associated with certain areas of the brain (for example, certain areas in the brain left hemisphere become specialised to some language functions, i.e., the Broca’s and Wernicke’s areas become associated with speech comprehension and production). Therefore, according to this belief, the plasticity of the brain fades with age and with the increasing specialisation of the different hemispheres and areas of the brain. However, recently neuroscientists, equipped with the complementary aid of brain neuroimaging and mapping techniques (e.g., functional magnetic resonance imaging, magnetoencephalography, electroencephalography, diffusion tensor imaging), have discovered that the mature brain is far from being fixed as previously thought; it has the ability to continuously adapt its structure and function based on internal and external environmental changes and/or input such as experience, ageing, hormones, illness, injury and learning, meaning that the brain remains plastic throughout life, even after injury; it is never resting.

* Studies of LA lend empirical support to the CPH (e.g., Birdsong, 1999; Birdsong & Molis, 2001; DeKeyser, 2000; Hurford, 1991; Lenneberg, 1967; Smith, 2004).

** Neurolinguistics is the science that studies the neural mechanisms in the brain that control comprehension, production and LA.
For a more detailed discussion about plasticity and structural and functional brain changes, refer to Allendorfer et al. (2012), Brown et al. (2005), Cramer (2008), Crosson et al. (2005, 2007, 2009), Epstein-Peterson et al. (2012), Fernandez et al. (2004), Fridriksson (2010), Kleim and Jones (2008), Marcotte et al. (2012), Menke et al. (2009), Ostry et al. (2010), Perani et al. (2011), Saur et al. (2006), Saur and Hartwigsen (2012), Szafarski et al. (2006), Thompson et al. (2010), Zatorre et al. (2012) and Zipse et al. (2012); or for a review, the interested reader is referred to Alsaedi (2023).

These scientific findings lead to the conclusion that the theory about the loss of brain plasticity during natural maturation cannot explain why language learning is affected by delayed exposure to a language; it cannot explain why an L2 can be complex for adults to learn and even when they succeed, native-likeness in L2A cannot be attained by the overwhelming majority of L2 learners. Yet, until now, the overwhelming majority of L2 researchers tend to think of plasticity as a phenomenon confined to early development; most of them take it for granted, and therefore, evidence supporting plasticity is generally ignored. This dogmatic belief, in my view, has serious impacts on the progress and development of L2 research. Its implications can be illustrated primarily along the following two dimensions:

(1). When considering the kinds of questions L2 researchers have been asking and how those questions have been answered.

(2). When considering the emergence of a plethora of theories, all of which were meant to describe how L2 is learnt, yet their authors have adopted widely differing views and have produced inconclusive, differing and even conflicting results.

The relationship between linguistic theory and SLA can be said to have started in 1967 with the publication of (The Significance of Learners’ Errors), in which Corder questioned whether the processes of L1A and L2A are essentially the same, guided by the same LA mechanism. Five years later, Selinker (1972) argued that the L2 learner constructs a Universal Grammar (UG) constrained grammatical

* The claim that the vast majority of L2 researchers accept the plasticity theory to explain why L2 becomes difficult for adult learners can be proven if the history of L2 research is traced, especially when considering the kinds of questions L2 researchers have been asking ever since SLA/SLL became an independent field of inquiry and how those questions have been answered. This point becomes clear when discussed later.
system that may be different from the syntax of their L1 and L2 – a non-defective developing system with its own rules. He refers to this L2 linguistic system as interlanguage (IL)*.

Selinker’s profound idea has been significant and remains so, in that the ultimate goal of SLA research has been the same ever since: to describe and explain the nature of the linguistic systems that L2 learners develop (refer to White, 2003). However, because linguistic theory provides the baseline for SLA research and has been under regular theoretical revisions ever since, the questions asked about the nature of IL are regularly changing. This holds true when we consider the ultimate aims of all the other different theoretical approaches (sociocultural theory of SLA, usage-based theory of SLA, etc); they all describe learners’ performances (the actual use of language) to explain how an L2 is acquired. This never-changed/-changing goal obviously raises two logical questions: (1) does the description of performance really lead to explaining the underlying linguistic competences of L2 learners, or accurately explain how and why learning occurs? (2) Do describing and explaining IL competences lead to explaining why learning fails to occur?

As for the first question, one can argue that describing learners’ IL competences does not lead to explaining such complex abstract systems in most cases**. This can be attributed to the facts that:

i. each learner has a unique underlying linguistic system with its own rules that is different from other L2 learners (Selinker, 1972);

ii. optionality/variability is a central feature of the adult L2 learner’s IL system, even that of a very advanced learner (cf. Lardiere, 2008; Lowie & Verspoor, 2015; Orfitelli & Grüter, 2013; Selinker, 1972; Sorace, 2003; White, 2003);

iii. performance is not on all occasions a perfect reflection of competence (Chomsky, 1965);

* For more detailed discussion about the history of the L2A research, refer to Thomas (2004).

** Description in general can lead to neither explanation nor full understanding. This is a fact easily proven and cannot be refuted from a logical point of view. To illustrate this point, imagine medical doctors have merely been describing the symptoms of COVID-19 since 2019; would they have been able to find a cure for this disease? Of course, they would not. Before they found a treatment/drug (i.e., vaccine) for COVID-19, they had to understand the nature of this disease by asking questions like: what causes this disease? What is it, a virus? How does it behave? And so on.
iv. the way in which experiments are done affects the results; this is because the linguistic and non-linguistic factors/variables that might influence the reliability of the collected data cannot all be controlled.

As for question two, from a philosophical perspective, it could be argued that describing and explaining the linguistic systems that L2 learners develop does not lead to explanation of failure – why learning fails to occur. This is simply because:

– the learner’s correct use of Y, say here the use of an active clause as in (i), does not guarantee the correct use of the target structure in all occasions (see research related to optionality/variability in L2A):
  i. The thieves stole the jewels.

– the learner’s learning of Y does not entail learning of Z, say here the passive clause as in (ii):
  ii. The jewels were stolen by the thieves.

– non-use of the passive clause does not mean unlearning of the target structure; a learner always has the option of not producing it (see research related to avoidance in L2A, i.e., Ortega, 2013; Saville-Troike, 2006; VanPatten & Benati, 2015).

Therefore, the correct use of active clauses does not explain the lack of use of passive clauses. Long (1993) argues that ‘it would be unwarranted to assume either (a) lack of knowledge on the basis of non-use, or (b) that error-free performance on what the learner did say or write can be interpreted as nativelike competence in all unobserved domains, as well’ (p. 209). This is predicted because performance is an indirect window to competence (Chomsky, 1965). We can thus conclude that any adequate theory of L2A must be capable of explaining both why learning occurs and why it fails to occur. Unfortunately, we do not have such a theory yet. My argument here will become clearer as I discuss the importance of having a unified theory in the following section.

Therefore, I think one of the primary goals of authentic SLA research is to understand, explain and justify the nature of IL competence, not just to describe it. However, this goal cannot be attained unless the cognitive system(s) internalised within the brains of L2 learners is/are studied. Therefore, the question that L2 researchers should have asked first is: What happen inside the brain at a certain
age(s) that makes it lose its innate ability to masterfully acquire the complex knowledge of language?

To find the correct answer(s) for this question, L2 researchers need to treat the brain as a testable scientific hypothesis. For example, because knowledge of language must be stored somewhere within the L2 speaker’s brain, and because there are physical laws, which the electrical and chemical events in the brain obey, L2 researchers, before trying to find answer to the aforementioned primary question, need to ask questions such as:

1. What, where and how are the physical mechanisms that serve as the material basis for L2 mental knowledge?
2. Is there some relationship between the L2 computational system in the mind and the physical structures of the brain – localisation of function in the brain?*
3. What are the potential contributors/factors (the mental ones) that could prevent or restrict L2 mastery, such as consciousness or memory?

Answers to these questions need to be compared with answers to the following questions to uncover clearly the reasons behind the marked difference in outcome between the child L1 (complete success) and adult L2 (varying degrees of partial success):

1. What are the mental mechanisms that allow children to masterfully acquire their NL(s)?
2. What happens inside children’s brains that makes it possible for them to masterfully acquire the complex knowledge of language? In other words, are the physical structures of children’s brains different from adult ones?
3. Is there some relationship between the L1 computational system in the mind and the physical structures of the brain – localisation of function in the brain?

Answers to these questions are difficult but possible with the advent of modern methods of brain scanning. However, to answer them, large-scale collaboration is required among theoretical and experimental neuroscientists, neuro-linguists, psycholinguists, syntacticians, and mathematical and computational linguists – the power and influence of science increase when scientists from different fields of study build up

* This is an important question. This is because recent studies have shown that the left inferior parietal cortex is larger in bilingual brains than in monolingual brains.
networks of support. Finding answers to these questions is central to further exploring and deeply understanding the nature of SLA*. They will open up venues for SLA thought; they could also raise further practical questions. Furthermore, such answers may help linguists move towards proposing a unified theory of SLA and learning. Unfortunately, current L2 research cannot lead to it – having a unified theory. This is simply because L2 researchers still treat the brain as just a philosophical theory. Evidence that may support this claim comes from the fact that different theoretical approaches adopt widely differing views of SLA/SLL, yet try to explain the same phenomenon – L2A. These theories produce different and seemingly conflicting claims; in fact, in one theory we can find conflicting hypotheses and inconclusive responses to any question investigated.

In the following sections, I will propose some assumptions, hoping to throw light on the potential causes of the phenomenon of why an L2 can be complex for adults to learn. These assumptions will be turned into questions to build new testable hypotheses for future research and could provide topics for more specialised scientific articles.

Method

To achieve these intriguing goals, previous research on psycholinguistics and neurolinguistics is critically reviewed.

Results

L1A vs L2A: Brain Automated Guided Process vs. Multitudinous Autonomous Process

It is believed that the course of child L1A is guided by a biologically endowed innate language faculty within the brain. This faculty provides children with a genetically predefined transmitted algorithm (i.e., rules and principles) for acquiring their L1(s). This means that the child brain is a genetically programmed organ with a built-in automatic system that performs a specific function in an efficient manner once activated by exposure to linguistic input. Therefore, the output of this guided process

* Finding answers to these questions is also central to basic science, education, medicine and so on. Scientists from all these disciplines can take the provided insights further.
is always a deterministic system – an internalised linguistic system, also referred to as the ‘l-language’ (Chomsky, 1986: 23), that forms the grammatical competence of the native speaker of a given language (‘the speaker/hearer’s knowledge of his language’ (Chomsky, 1965)), which allows the speaker to produce an infinite number of possible utterances and to intuitively reject the impossible ones, leading to native mastery of language. This automaticity may explain why L1A is an entirely unconscious and unguided activity, in the sense that children do not intentionally learn to have an NL and do so without the benefit of instruction (see Chomsky’s published works cited earlier).

However, at a certain age around puberty, the brain starts, to a greater extent, losing this automated ability to acquire language solely guided by the principles of language faculty. Adult L2 learners start also to rely on aspects of the mind other than principles specific to the language faculty. Rather, older learners may depend on more general properties of computation and general properties of cognition, including learning strategies such as generalising from particular instances to whole categories, problem-solving abilities, trial and error, and explicit instruction – learning knowledge that is formed based on conscious information/learning. Such conscious knowledge is not available to learners all the time unless it is converted to implicit knowledge. It is argued, therefore, that these general learning abilities, which are affected by learners’ internal psychological factors and external conditions, are not as effective for language learning as the more specific, innate capacities that are available to the young child. This conscious guided learning activity may explain why the overwhelming majority of adult L2 learners’ end-state ILs fossilise at some particular developmental stage that is not native-like. For a review of the contemporary approaches to SLA, the interested reader is referred to Mayo et al. (2013).

It seems to me that SLL is a multitudinous autonomous process. It evolves as a result of increasing (1) exposure to L2 linguistic input, (2) intrapersonal communication (self-to-self communication – the inner speech – which plays out in the mind of one individual without externally expressing the message, which is associated with various specific cognitive processes with some level of oversight, including thinking, reasoning, judgement, problem solving, reflecting and mediating) and (3) interpersonal communication, which is an exchange of information between the language learner and other language users.
It is also a learning process that is affected by, but at the same time to varying extents adapts to, dynamic social environments and personal psychological needs/factors. Therefore, the output of this multitudinous autonomous learning process is usually a non-deterministic system – a system that even for the same input can exhibit different behaviours on different linguistic occasions (see research related to L2 intraindividual variability). However, this linguistic system that is created by one learner, in the sense that each L2 learner creates their own system that is different from the others, is a non-defective system with its own rules that always obeys the general generative rules of natural human languages because it may be different from the syntax of the learner’s L1 and L2; thus, it is controlled, but partially guided, by the principles of language faculty. For a more detailed discussion about the nature of this UG-constrained grammatical system, refer to Lowie and Verspoor (2015), Mitchell and Myles (2004), Orfitelli and Grüter (2013), Selinker (1972) and White (2003)*.

This distinction between the processes of L1A and L2A can obviously raise a number of intriguing questions, but let us now consider in this section only the following crucial ones that are meant to address the structural developmental changes that basically occur in language-relevant brain areas in children and adults:

(1). *What are the biological, physical, chemical and so on characteristics of children’s brains that make it possible for them to masterfully acquire the complex knowledge of language?*

(2). *What happens physically, chemically and so on inside the brain at (a) certain age(s) that makes it lose its innate ability to masterfully acquire the complex knowledge of language?*

To answer these questions, scientists need to chart brains at different stages of development. Namely, they need to investigate if biological, structural, chemical, physiological and so on changes in immature and mature brains, that affect the nature(s) of L1A and L2A, occur after the end of the critical period. This will be the focus of the following section.

* In a separate article, the terms ‘automated’ and ‘autonomous’ will be discussed in more detail in trying to propose a more comprehensive theory accounting for the process of L2A – a unified one that hopefully will illustrate the idea that the L2 learning process is partially innate and, at the same time, is cognitive, social, individual and linguistic – a multifaceted process.
Two Different Brains: The Structural, Physiological, Chemical and so on Characteristics of Children’s and Adults’ Brains

A few researchers have begun to chart the biological, structural, organisational and developmental changes that exist in immature and mature brains (cf. Bruer, 1999; Cramer, 2008; Kolb & Whishaw, 1998, Lagercrantz, 2016; Liben & Müller, 2015; Rubenstein & Rakic, 2013; and the references cited later). These studies, for example, have shown that the nervous systems in immature and mature brains are structurally and physiologically different. It is true that the basic structure of the brain is established before birth by our genes. At birth, a child is born with about a hundred billion brain cells, known as neurons. Each neuron has about 1,000–2,500 synapses – the connections that grow between neurons. As the infant starts to explore its world and learn new things/skills, the brain undergoes a wave of neuronal connections. By two or three years old, the number of synapses per neuron increases to about 15,000. These trillions of synapses turn a collection of billions of brain neural cells into a complex network of neural circuits.

Changes in brain structure continue into middle childhood, across adolescence and adulthood, and through older adulthood. The brain remodels itself constantly to become an organ that is physically different from what it was in the preceding developmental stage (cf. Huttenlocher, 2002; Stiles, 2012; Szaflarski et al., 2006). For example, Perani et al. (2011) illustrates using diffusion tensor imaging that some of the fibre tracts that connect language-relevant brain areas in adults are in place in infants, whereas others are not. Such constant development can also be illustrated by neurological changes in the brain. The neurological changes include neuronal proliferation in certain brain areas, neuronal death and dendritic pruning (Campbell & Whitaker, 1986). For example, by middle childhood, it is believed that the brain undergoes a wave of synaptic pruning. Namely, by the age of five, the number of neurons and synapses halves (50 percent lower) compared to their number found during early childhood. This pruning process snips away the unused synapses, leaving only those ones between neurons that managed to form circuits. At age six, the brain is already at 90 percent of its adult volume (cf. Goyal et al., 2018; Goyal & Raichle, 2018; Kuzawa et al., 2014; Raichle, 2006; Raichle & Gusnard, 2002; Steiner, 2020).

As the young adult brain ages, it continues to experience pruning. Over time, neuronal death and dendritic pruning continue steadily for
the next six decades or so and lead to a great reduction in the number of neurons and connections between them. Eventually, the aged brain loses about 5–10 percent of its weight and 15–20 percent of its volume between ages twenty and ninety. This shrinkage occurs not only through neuronal death and dendritic pruning but also through reduction of grey matter – neurons and nerve fibres. Sowell et al. (2003) find that regions in the frontal lobe show decreases in grey matter density from age seven and beyond. In addition, the density of the myelin sheath that helps speed up the electrical signal sent by the axons grows thicker (Campbell and Whitaker 1986)*. Therefore, the remaining nerve cells in the ageing brain begin to slow down in their transmission of electrochemical impulses. This causes some decline in reaction time, the speed of perception, decision-making and other functions of the executive centres of the frontal lobes (cf. Turkington & Harris, 2009; in addition to the references cited earlier). The frontal lobe is one of the four major lobes of the cerebral cortex in the brain – the frontal lobe, the parietal lobe, the temporal lobe and the occipital lobe. The frontal lobe is responsible for managing higher-level executive functions. Executive functions refer to a collection of cognitive skills including working memory, verbal fluency, reasoning, judgement, problem solving and abstract thinking. The frontal lobe is considered our behavioural and emotional control centre and home to our personality. It also contains Broca’s area, which is associated with speech ability (for more detail, refer to Blumenfel, 2010; Kolb & Whishaw, 2015; Leisman & Melillo, 2015; Lezak et al., 2012; Mendoza & Foundas, 2011; Von Bartheld, 2016).

It is true that the brain continues to experience pruning throughout life. However, billions of neurons and trillions of synapses still remain. Because the brain never loses its ability to learn new activities, skills or languages even into old age and because changes associated with learning occur mostly at the level of connections between neurons, new connections form and become more efficient in their responses to external stimuli. As a result, the internal structure of the existing synapses changes, and therefore, the areas in the brain that deal with this type of knowledge/skill grow and become physically different. For example, Mechelli et al. (2004) and Costa et al. (2016) find

* Axons are very thin nerve fibres that carry nerve impulses away from a neuron (nerve cell) to another neuron.
that the left inferior parietal lobe is larger in bilingual brains than in monolingual brains. The inferior parietal lobe is a key area in the parietal lobe. It is involved with diverse cognitive functions, such as attention, memory, language and social cognition, that define human interactions. It houses Wernicke’s area, which helps the brain understand spoken language (for more detailed discussion about the functions of this lobe, refer to Numssen et al., 2021; Schmahmann, 1991; Singh-Curry & Husain, 2009).

The discussion so far has shown that there are developmental, structural, organisational and chemical differences between children’s brains and adults’ brains. As the child grows into an adult, different regions of the brain develop, grow and change at different rates. Such inherent changes in the brain lead to receptor changes because they must result in changes in neurotransmitters and other neuroactive substances and, therefore, are expected to affect the nature of language development that occurs after the end of the critical period. In other words, such changes in the brain suggest that the process/pattern of L2A is different from the process/pattern of L1A. Otherwise, one would expect that L2A should depend on the previously existing neurobiological systems used in L1A that have become specialised for language at early adolescence. However, this is not the case; Costa et al. (2016) and Mechelli et al. (2004) find that the left inferior parietal lobe is larger in bilingual brains than in monolingual brains. In addition, Sweeney (2009) mentions that bilingual children activate smaller regions of their brain than do adult learners, who draw on more widespread cortical regions when communicating in their non-native tongues. These findings lead to a logical conclusion that the brain changes – namely, the differences between immature and mature brains – play important roles in adult L2A. After all, I think that in a genetically programmed brain nothing happens haphazardly; that is, any change in the brain must have purpose and function.

Having described some of the structural, organisational and functional characteristics that distinguish children’s and adults’ brains, and to set the discussion in the context of LA, I will now raise and propose some questions and assumptions in the hope of shedding light on the potential causes of the phenomenon of why SLL is affected by delayed exposure to a language. These questions and assumptions will
generate new theoretical and practical questions and testable hypotheses for future research. For example:

*Why does a child’s brain first undergo a wave of synaptic connection and then, by middle childhood, it undergoes a wave of synaptic pruning?*

To answer this question in the light of the preceding discussion, one can argue that a baby is born with a brain that is already wired for the basic functions of survival, such as regulation of heartbeat, breathing and digestion. However, once the baby enters the world, their brain undergoes a wave of neural connections; the baby’s environment enhances such neural connectivity and formation through learning – everything, both good and bad, is a kind of ‘learning’ for the brain. Nonetheless, this explosion of synapse formation between neurons during early childhood ends soon after; that is, by middle and late childhood, the brain is believed to undergo a wave of synaptic pruning. Scientists believe that this pruning process is important because it saves 50 percent of the brain’s daily energy consumption – at this developmental stage, the brain demands 20 percent of the calorie intake, instead of over 40 percent of the daily intake that is diverted to our brains during early childhood (for more detailed discussion see, among many others, Goyal et al., 2018; Goyal & Raichle, 2018; Kuzawa et al., 2014; Raichle, 2006; Raichle & Gusnard, 2002; Steiner, 2020).

Indeed, this seems to be a plausible answer to the aforementioned intriguing question, but one remains sceptical if considering how and why the brain’s neural synaptic connections are formed. New synaptic connections between neurons form in response to learning. As a result, the internal structure of the existing synapses changes and grows and therefore complicated neural networks are created. So, the preliminary question to be raised now is why after managing to create efficient neural networks, half of the already precious formed synapses in the child’s brain became unused by the age of five? We know for sure that these synapses were formed at the beginning for specific purposes and therefore used to have functions. This is because learning is only possible through structural and functional changes in the brain (Costa et al., 2016; Mechelli et al., 2004). So, what is happening inside the brain at a certain age that makes such a large number of synapses become out of service? Clearly, this question is still open for
further investigation. However, researchers, to find possible convincing answer(s) to the aforementioned primary question, indeed need to ask further questions such as:

*Why is a child’s brain voracious – burning up twice as much energy as an adult’s brain?*

Because an infant is born with a brain that is biologically wired only for the basic functions of survival, it is possible that a child’s self-organising and -controlling brain at the very early stage of development consumes too much energy to form through learning new complex circuits by strengthening the synapses connecting the neurons so that the left hemisphere and the right hemisphere of the brain become harmonised into a single potent system. This harmonisation (a unifying process that probably makes the different parts of the brain synchronise and communicate with each other) may allow the brain to be self-regulated. Perhaps it is these harmonisation and self-regulation processes that explain why all normal children unconsciously and invariably acquire successfully to normal, native-like levels the target language(s) they are exposed to. Hence, one can argue that the unconscious mind is in charge here and, therefore, solely controls and guides the process of L1 development. The power of the unconscious mind is worth highlighting here because it provides a plausible explanation to the question of how children acquire a remarkably complex grammatical system with relative ease and without the benefit of instruction. Research has shown (cf. Baars & Gage, 2010; Dimitriadis & Psychogios, 2020; Levitin, 2014; Markowsky, 2021; Murphy & Honey, 2016; Young & Jennings, 2022; Zeuch, 2008) that the processing power of the unconscious mind is immensely more powerful than that of the conscious mind*. Some researchers argue that unconscious processes can carry out every fundamental high-level cognitive function that conscious processes can perform (cf. Baddeley, 2007; Deters, 2022; Dijksterhuis & van Olden, 2006; Hassin & Sklar, 2014; Wilson, 2004; Zeuch, 2008).

The discussion about the power and function of the unconscious mind raises an important question in relation to LA: how does the unconscious mind control and guide children in the course of acquiring...
their NLs? This is a difficult question; I am not aware of any study that has provided a thorough answer to this question. However, one way to investigate this question is to look at the brainwave frequencies that underlie language development – how they pattern, shift and change as infants grow and develop.

The brainwaves are the language of the brain. They provide information about a person’s health, state of mind, age and the type of learning they do (see Clarke et al., 2001; Colletti, 2021; Frick & Wilbarger, 2017; Gandhi et al., 2023; Lipton, 2005; Perone et al., 2018; and the references cited later). This is because each pattern of brainwaves (Delta, Theta, Alpha, Beta, Gamma etc.) is associated with a specific brain activity, condition, learning and so on. For example, it has been found that each type of learning is distinguished by the brainwave patterns it produces; Ham (2017) argues that explicit learning is accompanied by Alpha and Beta brainwaves oscillating at 8.25–30 Hertz (Hz), whereas implicit learning is accompanied by Delta and Theta brainwaves, oscillating at 0.5–8 Hz. Such findings suggest that there are different mechanisms at play during explicit versus implicit learning. In what follows, I will illustrate briefly age-related change in brainwaves from early childhood to adulthood in relation to LA.

As infants develop into toddlers, then preschoolers, then young students, then adolescents, brainwave patterns shift from the slowest to faster and faster frequencies. From birth to the age of two, infant brains are predominantly in the slowest frequency band of 0.5–4 Hz, which is the Delta band (Colletti, 2021; Lipton, 2005). Within this Delta band, the infants are able to use 500 words with very simple syntax (Gerber & Prizant, 2000: 116–117). In adults, Delta brainwaves are associated with deep dreamless sleep (Colletti, 2021; Frick & Wilbarger, 2017).

At two years of age, the first shift in brainwaves occurs; toddlers’ brainwave frequencies enter Theta (4–8 Hz), which will be the dominant rhythm in children’s waking state up to six years of age. My interest here is not in the studies that have addressed this question from the theoretical perspective of Chomsky’s UG (refer back to section 1 to see the discussion about the innateness hypothesis). My interest here is in the studies that are conducted to investigate the mechanisms at play during the implicit acquisition of language, and in those ones that have addressed the relationship between brain developments/changes and language development; namely those studies that treat the brain as a testable scientific hypothesis.

** Brainwaves are electrical signals that oscillate at different frequencies that are produced by neurons when they fire in synchrony.
age (Lipton, 2005: 172). During the phase of Theta wave frequencies much of child LA occurs; the child’s linguistic knowledge of language develops rapidly (Colletti, 2021; Schneider et al., 2018). Interestingly, in adults, Delta band frequencies are associated with sleep and deep creative dreams (Frick and Wilbarger, 2017). This obviously raises the question of what it is about the lowest brainwave frequency bands (Delta and Theta) that facilitates the acquisition of language; notably, Ham (2017) observed that implicit learning is accompanied by Delta and Theta brainwaves, oscillating at 0.5–8 Hz. In any case, the connection between brainwaves and LA remains poorly understood; very little research has been conducted to investigate this issue. Therefore, this remains an open question for future research.

It should be mentioned at this point that new extremely slow brainwaves have recently been discovered, called Epsilon. The Epsilon are very low-frequency (below 0.5 Hz), below that of Delta waves, which start at 0.5 Hz. Most electroencephalogram devices are not able to measure frequencies below 0.5 Hz; it requires sophisticated equipment. Therefore, we do not have many scientific data to understand the Epsilon, but scientists know from limited number of studies conducted on Tibetan monks and yogis that Epsilon is characterised by extraordinary states of consciousness – ones that are similar to the most advanced states of consciousness that appear to be associated with Hyper-Gamma brainwave activity (at 100 Hz) and Lambda brainwave activity (at 200 Hz). The only difference is that the state of consciousness that is accessed through the Epsilon brain waves is achieved through a very drowsy state that typically would allow the person in question to facilitate a deep sleep, but when that person accesses this most advanced state of consciousness through the Hyper-Gamma or through the Lambda, they achieve it in a highly awakened state*. Interestingly, when these brainwaves are dominant, despite the huge differences in frequency, the brainwave electrical activity between the right and the left hemispheres synchronises. This synchronisation of the cerebral hemispheres only happens in special circumstances of consciousness, that is, the moment when the answer to a problem occurs. For more information about these extraordinary three types of brainwaves (Epsilon, Hyper-Gamma and

* How can our deepest states of relaxation be the doorway to our most awakened states of consciousness? This is an interesting question; answers to it will help us to find better answers, instead of the controversial ones, to the question: what is consciousness?
Lambda) that do not receive significant attention, see Braden (2022), Centre for Neuroacoustic Research (n.d.) and Fannin (2019).

Based on our limited understanding about the nature and function of the Epsilon brainwaves, some appealing questions related to LA can now be raised: Do young children’s brains produce the lowest brainwave frequency band ever known – the Epsilon? Does this wave type facilitate the acquisition of language by allowing children to enter a mysterious state of consciousness? To my knowledge, no researcher to date has investigated these questions. Answers to such questions may change our understanding about the nature of L1A and also have serious implications for linguistic theories. For example, if young children’s brains are found to produce the Epsilon waves, can they access that most advanced state of consciousness that adults can have access to in very rare recorded situations via the Epsilon? If so, do researchers need to assume that children come to the task of LA with the unconscious prior linguistic knowledge part of genetic endowment that solely guides them in the course of acquiring their NLs? It should be stated here that the Epsilon state seems to be almost a secretive one that is somewhat shrouded in mystery. Therefore, further research is needed to understand it.

As children grow, age-related change in brainwaves continues; namely, at around age six, another type of faster brainwaves starts to emerge – Alpha brainwaves (Clarke et al., 2001; Colletti, 2021). The Alpha waves have a frequency range of 8–11.75 Hz. Alpha waves are associated with being relaxed, internally focused and with a mental state of open awareness or quiet readiness. Lipton (2005) equates them with a state of calm consciousness that can facilitate our own inner body and emotional awareness (174). There are few differences in the associations of Alpha waves between children and adults (Schneider et al., 2018).

As a child matures, activity in the faster frequency bands increases (Clarke et al., 2001). Around twelve years of age, two faster brainwaves start to emerge – Beta waves and Gamma waves. Beta waves (12–35 Hz) are associated with focused consciousness, logical thought processes, analysis, organisational skills and productivity (Colletti, 2021; Frick & Young 2009). Gamma waves (35–80 Hz) are also associated with states of peak performance; they have been linked to a wide variety of higher cognitive processes including attention, perception, learning, memory and information processing (cf. Basar et al., 2000;
Between the age of six and twelve the final stage of language development occurs, in which ‘the child’s syntactic, semantic, and pragmatic abilities are well-developed and sophisticated’ (Gerber & Prizant, 2000, 121). It should be restated at this point that during this age, namely between late childhood and early adolescence, the child brain specialises, and different regions of the brain develop. For example, certain regions of the left hemisphere (e.g., Broca’s and Wernicke’s areas) become specialised for some language functions, and the frontal lobe, which is the last part of the brain to fully develop, becomes associated with various specific cognitive tasks, including working memory, verbal fluency, reasoning, judgement, problem solving and abstract thinking; it also plays a role in personality traits such as planning and organisational ability, ethical and moral sense, and overall emotional control (for more detailed discussion, refer to Alvarez & Emory, 2006; Clark et al., 2008; Goldman-Rakic, 1987; Holroyd & Coles, 2002; Kolb, 1984; Leisman & Melillo, 2015; Lezak, Howieson & Loring, 2004; Liben & Müller, 2015; Rolls & Grabenhorst, 2008; Szafarski et al., 2006; Wilson et al., 2010).

An important question to be raised now is: why is the frontal lobe the last part of the brain to develop? However, researchers, to find a plausible answer(s) to this question, need to ask further questions such as:

(1). Is it because this part of the brain is most sculpted by environment and experience and therefore is the least constrained by genes?**

If this is the case, keeping in mind the executive functions of this part of the brain and the plausibility that language and its development are the products of the interaction of multiple brain areas (e.g., Broca’s

For more information about this stage of language development, see research related to acquisition of communicative competence – the capacity to utilise language in a grammatically correct way in different and appropriate social settings (cf. Bonvillain, 2003; Greene, 2016; Kiessling & Fabry, 2021; Saragih, 2016).

From the previous discussion in part one, we know that everyone’s brain is structurally different from every other brain on Earth – the connections that grow between neurons, the synaptic pruning, the everyday interactions with the world and so on build a brain that is unique to one individual, and this is probably what makes us so different.
area, which is associated with speech ability, and Wernicke’s area, which helps the brain understand spoken language, are parts of different lobes of the cerebral cortex in the brain – the frontal lobe and the parietal lobe respectively), one can ask how does the development of this part of the brain affect the nature of SLA? In other words, what does the development of the frontal lobe tell us about the role of the general properties of cognition, the role of the personality traits, the role of conscious learning, the role of the experience and the environment, and the role of UG principles in the process of SLA?

One way to address these questions is to investigate the relationship between language and thought. Such a relationship has been documented in anthropological, psychological and linguistic research. For example, numerous studies have shown that the language that we speak shapes the way that we think, meaning that it shapes how we construct our individual perceptions of reality, build our opinions and interpret the incredibly complex knowledge systems that we have. For a more detailed discussion, see Boroditsky (2011) and much of her subsequent work, and Casasanto et al. (2004).

Chomsky (2015a) argues that we ought to view ‘language as essentially an instrument of thought’ (16); he argues that language is evolved and designed as a mode of creating and interpreting thought. Thought and thinking refer to conscious cognitive processes that can happen independently of sensory stimulation.

Because the frontal lobe is considered home to our high-level cognitive functions, because it is considered our behavioural and emotional control centre and home to our personality, because language is considered as ‘a system of thought’ (Chomsky, 2015b) and because the language that we speak shapes the way that we think, it seems that the development of this part of the brain influences the way we learn and process a second language.

(2). Is the development of this part of the brain linked to the emergence of fast oscillations in the Alpha, Beta and Gamma ranges?

The discussion in this section has shown that the frontal lobe is considered home to our high-level cognitive functions such as logical thought processes, analysis, reasoning, judgement, problem solving and organisational skills. Such cognitive processes are associated with specific patterns of brainwaves, namely the fast brainwave frequencies
(i.e., Alpha, Beta and Gamma). The discussion in this section has also shown that such fast brainwaves start to emerge successively during middle childhood and across/through adolescence – between the ages of six and twelve. Similar results are relatively obtained in regard to the age at which such higher cognitive functions are acquired by children and adolescents (cf. Lehrer & Schauble, 2015; Müller & Kerns, 2015; Ricco, 2015). This suggests that there is a correlation between the emergence of fast oscillations and the full development of the frontal lobe. However, further research is necessary before we can draw conclusions about this possible correlation.

This possible relationship raises the questions of whether certain types of brainwaves play a functional role in learning an L2, whether certain types of brainwaves can predict a person’s ability to learn an L2 and whether such waves can predict how quickly someone will learn an L2. Little research has been conducted to investigate these questions. For example, Prat et al. (2016) find that faster L2 learners have higher Beta and Gamma wave activity in their brains; they also find that the fastest learners learn twice as quickly as the slower ones. This suggests that *not all but only* instructional methods that engage L2 learners in the learning process and require them to do language exercises that need logical thought processes, critical thinking, analysis, organisational skills and so on can help them learn faster and perform at their best because they benefit from increased patterns of brainwave activity. Does this explain why there is disagreement among researchers about the role of instruction in SLA? The possible role for instruction ranges from significant to helpful to constrained to no effect or, potentially, even detrimental (cf. VanPatten et al., 2020).

To summarise, the discussion in this section has led to the conclusion that researchers interested in SLA need to treat the brain as a testable scientific hypothesis, rather than merely a philosophical theory. Once they do so, various unexpected theoretical and practical questions can be raised – questions that can open new perspectives in our understanding of both the nature and course of L2A and the nature and function of the brain. In short, this method, which integrates brain, brain development, language, SLL and the learner at every moment, will not only generate new predictions but also help to account for already observed L2 phenomena for which no good explanation currently exists.
Conclusion

My goal in this article is to emphasise the need for treating the brain as a testable scientific hypothesis, rather than merely a philosophical theory, and to illustrate the need to integrate L2, brain, mind and the learner at every moment to account for LA. These, in my view, will open up venues for SLA thought, will also help to account for already observed L2 phenomena for which no good explanation currently exists, will open various unexpected theoretical and practical questions, will generate new predictions and, thus, may help researchers to move towards a more comprehensive theory of SLA. Having a unified theory is important if we want to understand (1) the nature of IL competence, (2) the language learning process and (3) the language learner and their role in the acquisition process.

It should be restated that the purpose of this article is not to undermine the L2 research done so far. It goes without saying that contemporary SLA research has expanded our knowledge about the nature of IL, the language learning process, the language learner and their role in the acquisition process and so on. However, this article is meant to push the field of SLA to be more scientific. Basically, it seeks to push the field into a new era. I believe that science will improve and change, especially brain science. No one can make accurate predictions about the future of brain science; science will ultimately take the human brain research to places we cannot yet imagine. Do you believe it is no longer a fantasy to turn brainwaves into words – translating thought into speech?* Does this not put humanity closer to a future in which people who cannot speak will be able to communicate? What are the applications and implications of this promising research on the field of SLA? It seems the only thing that is certain in science is that it will change and improve. Therefore, we linguists must take the lead. The departure point is that we feel free to ask new innovative questions and build new hypotheses.

* For more detailed discussion about innovative research concerning turning brainwaves into words, refer to Akbari et al. (2019), Angrick et al. (2019), Anumanchipalli et al. (2019), Guger et al. (2020) and Guglielmi (2019).
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**АННОТАЦІЯ**

**Вступ.** У статті оцінюються сучасні дослідження в галузі психології та нейролінгвістики з метою пошуку відповідей на питання, чому засвоєння першої мови (L1) дитиною ґрунтується на інших методах обробки, ніж засвоєння другої мови (L2) дорослими, і чому L2 може бути складною для вивчення дорослими. Ця стаття, по суті, є критичною оцінкою досліджень у галузі вивчення мови (ІМ) і пропонує нові напрямки для вивчення.

**Цілі.** Основна мета цієї статті – підкреслити необхідність розглядувати мозок як наукову гіпотезу, яку можна перевірити, а не просто як філософську теорію, а також проілюструвати необхідність інтеграції L2, мозку, свідомості та учня в кожний момент для пояснення процесу оволодіння мовою.

**Метод і результати.** Для досягнення цих інтриguючих цілей було критично проаналізовано попередні дослідження з психології та нейролінгвістики. Огляд показав, що мозок у дослідженнях SLA розглядався просто як філософська
теорія. Це, на мою думку, має серйозний вплив на прогрес і розвиток галузі у двох аспектах:

a. Це приводить до того, що дослідження стимлюються припущеннями, які перетворилися на догми і перешкоджають неупередженному мисленню.

b. Він змушує дослідників покладатися виключно на мовленневу діяльність учнів (фактичне використання мови) для опису та пояснення природи мовних систем, які розвивають учні L2 (компетенції), а також для пояснення того, як набувається L2. Однак ми всі знаємо, що продуктивність не у всіх випадках є ідеальним відображенням компетентності (див. Хомський, 1965, 1988).

Ці два моменти підкреслюють необхідність розглядати мозок як наукову гіпотезу, яку можна перевірити, а не просто як філософську теорію, і ілюструють необхідність постійної інтеграції другої мови (L2), мозку, розуму та учня в кожний момент часу, щоб пояснити, чому навчання відбувається і чому воно не відбувається.

Висновки. Стаття пропонує критичну оцінку попередніх досліджень у психолінгвістиці та нейролінгвістиці. У ній стверджується, що дослідження мозку у вивченні другої мови (SLA/L2A) тривалий час розглядалися лише як філософська теорія, що призвело до висновків, яким бракує фактичного нейролінгвістичного аналізу. У статті висловлюється припущення, що теоретичні пояснення того, чому діти опановують L1 швидше і легше, ніж дорослі L2, узгоджуються з нещодавніми дослідженнями мозку, які виявили відмінності у хвилях мозкової активності в ранньому і середньому дитинстві порівняно з дорослим віком. Це вказує на відмінності у засвоєнні мови між дітьми та дорослими з точки зору хвильової активності мозку, розміру сірої речовини та інших факторів.

Ключові слова: вивчення/засвоєння другої мови; дорослий, який вивчає L2; мозок/розум; сучасні дослідження SLA; майбутні дослідження SLA.