Resumen
The mission of cognitive sciences is to understand cognitive processes. In order to do that, a first wave of studies tried to simulate thought through computers; after many failed attempts, a second wave tried to study mind through a strictly reductionist neuroscientific approach. Today, both approaches appear as dualist and incomplete due to their blindness to the role of body, human societies and external environment.

Analysing the reciprocal influences between photography-based technologies and cognitive studies, we will try to shed light on a frequently recurring process in the history of cognitive sciences: the creation of a polarity between the ones who study cognitive functions separating them from physical substrate and those who study cognitive processes in a reductionistic way. In the final part, we will suggest an alternative approach to the problem, based on practical principles. While doing that, we will discuss some of the most recent studies on second language acquisition.

Palabras clave: Cognitive sciences, brain-imaging, second language acquisition, dualism, language ontogenesis

1. Introduction
Cognitive sciences are the set of disciplines that are focused on human mind and thought. Historically, we can recognize three main phases in the scientific debate generated
within this field of studies. The first phase we will take into account is *cognitivism*, in the sense described in 1991 by Francisco J. Varela, Evan Thompson and Eleanor Rosch; this paradigm is characterized by the idea that thought can be represented through a formal system of symbols. The second phase that we will talk about is the one characterized by a strong enthusiasm towards neuroscience, during which cognitive scientists started to believe in the possibility to explain thought recurring exclusively to the study of neurophysiologic processes occurring in the brain (Pennisi, Falzone 2010). Lastly, we will take into consideration the third phase of cognitive sciences, the stage of embodied cognition. According to this perspective, thought can not be explained by exclusively studying the biology of the brain: mind is *embodied*, and that means that, whether we look at them through a social or a non-social perspective, all out cognitive functions depend both on our bodily processes and on our interactions with the environments.

In this paper, we will try to analyse how the paradigm shifts in cognitive sciences history effected the debate about second language acquisition (SLA). In order to do that, we will answer the following questions: how did the change in the general historical paradigms on mind influence the study of cognitive processes engaged in SLA? What are the general theories of thought and mind that tell us about SLA? How does the dualism manifest itself in phenomena like SLA?

In §2 we will describe the principles of cognitivism and show how they influenced linguistic studies on SLA. In §3 we will get to the bottom of the criticism of cognitivist paradigm, analysing the neuroscientific reaction and the problems linked both to a *dis-embodied* paradigm such as the cognitivist one and a reductionistic approach such as a neuroscience free from the influence of cognitive sciences. In §4 we will present embodied cognition theories and propose some methodologies that, in combination with SLA studies, could help us to avoid typical biases. In §5 we will sum up our argumentations.
2. Cognitivism and second language acquisition

In 1936, Alan Turing conceived the notion of a machine (today known as Turing machine) that—through recursion—can resolve any kind of calculation. In other words, each time it should have been possible to formalize logical operations necessary to execute a calculation, the Turing Machine would have been programmed to do that calculation autonomously. This work showed the entire world the power of recursion: from a finite number of elements, it would be possible to make an infinite number of calculations.

In 1943, Warren S. McCulloch and Walter H. Pitts hypothesized that neural events should be represented and treated through the propositional logic. The success reached by this idea led the metaphors of “the brain as a computer” and “the mind as computations” to inaugurate a new era of philosophical enthusiastic Platonism. The main assumption of cognitivist approaches is that it is possible to explain and represent thought through formal simplifications.

In linguistic studies, the luckiest conceptualization underpinning this kind of dualism was probably the Universal Grammar made up by Naom Chomsky. In the same way cognitivism followed the dissatisfaction of founding fathers of cognitive sciences with behavioural paradigm, Chomsky’s scientific fortune followed the criticism he directed in 1957 at Skinner’s theory of language (Chomsky 2003). As is well known, Chomsky’s theory of first language (L1) acquisition had a great impact on scientific communities and linguistic studies since its first publication.

In Chomsky’s formulation, the main role of the linguist (and also of the child who is learning his L1) is to look for the implicit system of formal rules that speakers unconsciously master (Chomsky 1965). This study has to be done in ideal conditions (completely homogeneous speech-community; with unaffected speakers; without considering limitations of memory, or attention, etc…) (ivi). In a certain sense, the linguist will formally describe the formal structure of each sentence as a computer scientist would formalize logical operations to execute a
computation. The product of this research will be the Universal Grammar (UG), a formal structure to all languages that develop in the speaker thanks to genetics with the simple triggering of being immersed in a community of speakers.

The reason why Chomsky resorts to the analysis of formal processes is the pregnancy of the case of language for the platonic argument of the poverty of the stimulus (Chomsky 2005): human beings seem to have some implicit learning skills that cannot be explained exclusively in terms of an associative learning such as the one described by Skinner. As the Meno’s slave pictured by Socrate showed some geometric competence even though he had never received explicit mathematics education, children are able to produce sentences they have never heard before. In *Mind and body* (one of his famous Woodbridge Lectures given in 1978 at the Columbia University) Chomsky proposed an analogy between mathematic and linguistic faculties: the common feature they share is that they can be treated as *mental organs*. Does anyone learn how to growth his arms or to develop his sexual characters? Obviously, the body needs some stimuli to develop its arms or sexual characters, but the way it develops them is part of its genetic program (Chomsky 2005). According to Chomsky, we have no reason to consider the brain differently from arms or sexual characters: i.e. the environment has a “shaping effect” on perceptual and motor systems, but they are highly programmed and specialized by genetics (*ivi*). In the end, Chomsky explicitly suggest a comparison between the linguistic faculty and *mental organs*: they are both intrinsically predetermined by genetics, although shaped by experience (*ivi*).

Chomsky’s theory had a great impact on all linguistic studies, and the field of SLA was no exception. A lot of linguists (cfr. i.e. Bley-Croman 1989; Flynn 1987; White 1985) were attracted from the concept of UG. Since the problem of the poverty-of-stimulus occur both in L1 and in L2 acquisition, in the eighties philosophers of language and linguists started to wonder if UG also mediates L2 acquisition or not (White 2004). Very soon the question led academics to split in three different groups: the
proponents of the no access (or partial access) hypothesis; the proponents of the direct access hypothesis; the proponents of the indirect access hypothesis.

The proponents of the no access (or partial access) hypothesis highlight the differences between the L1 and the L2: Robert Bley-Vroman (1989), i.e., observed that L2 learners rarely reach the mastery of L1 learners and posited that—rather than the domain-specific UG—L2 learners use some kind of abstract problem-solving system. Supporters of the direct access hypothesis, on the contrary, highlight that L2 learners often learn grammatical properties of the L2 that do not show up in their L1 (Flynn 1987). Lastly, proponents of the indirect access hypothesis claim that L2 learners can use their L1 UG at the beginning, and that later they likely “build up” a new UG for their L2; according to this perspective, UG does not lack in L2 learners, but needs to interact with L1 in order to develop (White 1985).

3. Neuroscience and second language acquisition

Since its first formulations, cognitivism had a great success. It triggered artificial intelligence studies; built bridges among different discipline such as mathematics, biology and social sciences, promoting—in this way—the diffusion of interdisciplinary methodologies for the study of mind; inaugurated the field of experimental studies on self-organizing systems (Varela et al. 1991).

Unfortunately (or maybe luckily), however, cognitivism is not adequate to explain human cognition. In his Bright Air, Brilliant Fire (1992), Gerald Edelman exhaustively synthesized the most crucial criticism of cognitivism. Let’s consider some of them.

As we saw in the previous paragraph, cognitivism is based on the metaphor of mind as a computer. The existence of a Universal Turing Machine-looking-like “software” that could simulate any kind of calculation quickly led scholars to forget about the “hardware”. In other words, in the same way computer scientists have been given the opportunity to imagine an abstract software the functioning of which was not dependent
on the hardware, the study of thought suddenly forgot to take into account the role of the brain, the body, the environment, the society, etc. Moreover, the formal rules software’s functioning is based on are composed by a finite quantity of symbols that have meanings; these meanings are given by the programmer.

All these characteristics make a philosophical failure out of the metaphor of mind as computer. In fact, as pointed out by Edelman, our brain (the hardware in the cognitivist metaphor) is not previously programmed by genetics, rather is shaped in most of its parts by child’s (and even adult’s) interactions with environment and society. The meaning of symbols is not previously “designed”, but it emerges during experience. Moreover, symbols are never ambiguous in a Turing Machine; on the contrary, our sensorial experiences (the inputs in the cognitivist metaphor) have an analogical and ambiguous nature.

In adapting this concept to the linguistic studies, even Chomsky showed all the flaws of his argumentation. In fact, arms and sexual characters are structures, while language is a function: they cannot be treated as analogous phenomena because they are ontologically different. When Chomsky claims that the working of mind depends on unintelligible principles (Chomsky 2005:72), he is just giving life to a hypothesis that is unsustainable for cognitive sciences.

Nevertheless, there still exists an unsolved problem: how can we study mind without being dualist?

A frequently used solution is reductionism (Pennisi and Falzone 2010), according to which the study of physiology can explain complex concepts such as imagination, creativity, sense of self, consciousness, etc. I. e. a lot of studies investigate “the neurobiological mechanisms associated with spiritual practices” (Newberg 2014:1; similar exempla can be found in Paley 2007; Fingelkurts and Fingelkurts 2009). However, an approach based on these principles is destined to last even less than the cognitivist metaphor (Pennisi and Falzone 2010). As we will try to show, neurobiology gives us some important data, but they will always need a cautious philosophical analysis.
Let’s come back to our case study: SLA. In the field of SLA, studies conducted with brain imaging or other kinds of technology are progressively spreading out. There is a significant data that accounts this trend: in 2017, we conducted a systematic analysis of a sample of 445 researches on the topic “SLA in adulthood” (we adopted two main criteria to obtain the sample: the research had to be published in the previous 10 years and it had to be focused on the SLA in adulthood. To know all the details on the criteria we adopted, see Pennisi and Torricelli in press). 95 researches of the sample (more than the 21%) resort to technologies such as functional Magnetic Resonance Imaging (fMRI), Event Related Potentials (ERP), eye-tracking, Electroencephalography (EEG), etc. Among all these researches, 18 of them have been conducted using fMRI.

The last three letters in FMRI stand for Magnetic Resonance Imaging (MRI). MRI is a technique that creates magnetic fields the frequency of which is adjusted according to the object of study; in fact, the atomic nuclei of different bodies have different reactions to the absorption of the electromagnetic fields’ energy. When the object of study is the human body, scanners get tuned to the frequency of hydrogen nuclei, the most common in human body. Each nucleus emits the energy absorbed by the electromagnetic field; thus, the emitted energy gives us informations about the quantity and the quality of nuclei present in the subject. If we would change the characteristics of the electromagnetic fields, we would be able to distinguish different tissue types (Huettel et al. 2009). According to what we just said, we could describe, MRI as a sort of map that gives us a clear idea of the distribution of some kinds of nuclei. In the same way it happens in a photography, in MRI the matter autonomously position itself, giving us its representation through theoretically replicable constraints.

A MRI becomes “Funcional” (the F in FMRI) when, during the emission of magnetic fields, experimenters (or doctors) ask the subject to perform some kind of action. Usually, during this kind of studies, experimenters measure changes in blood oxygenation during the required activity. In doing so, they obtain
traces of augmented physiological activity in the observed brain areas (ivi).

Let’s analyse one of the studies conducted with fMRI among the 18 that make up our sample. In 2017, Barbeau et al. published on Neuropsychologia a study titled “The role of the left inferior parietal lobule in second language learning: An intensive language training fMRI study”. In this research, experimenters investigated the role of the left inferior parietal lobule in SLA. Experimental subjects’ brain areas involved in sentence reading were scanned before and after a 12-week intensive foreign language training. Measurements were both taken during L1 and L2 reading tasks. The following are the results and the comments that the authors collected in the abstract:

Of note, for the L2, there was higher activation at Time 2 compared to Time 1 in the left inferior parietal lobule (IPL) including the supramarginal gyrus. At Time 2 this higher activation in the IPL correlated with faster L2 reading speed. Moreover, higher activation in the left IPL at Time 1 predicted improvement in L2 reading speed from Time 1 to Time 2. Our results suggest that learning-induced plasticity occurred as early as 12 weeks into immersive second-language training, and that the IPL appears to play a special role in language learning (ivi).

The failure of phrenology occurred in 19th century taught us that localizationism does not work (Huettel et al. 2009; Pennisi 2011; Pennisi in press). Today, the relationships between cerebral structures and functions are investigated by neuroscientists aware of the fact that a cerebral area can be engaged in multiple functions and that a function can be performed in multiple ways. Although this awareness is well-rooted in modern neuroscience, a lot of the studies that are conducted with brain imaging or brain measurement techniques are subject to some biases. In the case of the article we just mentioned, there are some technical and philosophical issues we need to address. Let’s start with the analysis of technical problems.
The temporal resolution of the study made by Barbeau et al. (2017) had been set up to 10 seconds. Cerebral events occur in a few milliseconds. Figuratively speaking, we can imagine a researcher who wants to study the distribution of pedestrian traffic during night-time in New York through aerial photographs and suppose that, due to the low level of light, he is forced to set his photo camera’s shutter speed to 5 seconds. He will obtain a representation of the traces left by the slowest pedestrians, but will lose a lot of information at the same time. In order to solve this problem, researchers use to adjust the data through a statistical analysis based on the average of the different subjects; unfortunately, as highlighted by the philosopher Alva Noë, in this way, “scientists project their findings onto an idealized, stock brain” (Noë 2009:23; it. ed. P. 24). An uncritical acceptance of this compromise would mean proclaiming the victory of a revised neo-computationalism, and this is not what we need to aim for.

In addition to time resolution problems, fMRI is affected by spatial resolution problems. In order to collect their data, Barbeau et al. (2017) used a spatial resolution of 3.5 mm$^3$.

In a human brain there are 86 billion of neurons (16 billion of them are in the cortex) and 85 billion of non-neuronal cells (Herculano-Houzel 2009). Before 2009, we have never had a direct estimation of cellular density in the brain (ivi), and even now our knowledge on the topic is less deep than we think. I.e., the most accredited estimation made within modern neuroscience is the one proposed by Suzana Herculano-Houzel’s research group, but it expresses the quantity of neurons per gram of brain, not per millimeter. As highlighted by the researcher, neuronal density in human cerebral cortex has been estimated, within fifty years of research (1926-1987), at numbers that go from 8.750/mm$^3$ to 48.100/mm$^3$ (Herculano-Houzel 2011). Hence, the truth is that we don’t know exactly how many cells there are in 1 mm$^3$ of cortex, but we know that probably there are tens of thousands of them. According to this considerations, we cannot put the physiological activity observed in our brain during a fMRI in relation with a precise number of cells.
that are in that area. In order to solve this problem, experimenters usually rely on a subtractive paradigm by an inverse inference (Poldrack 2006). However, even this solution lead to some problems, the nature of which is perhaps more philosophical than technical.

Let’s go back to the study of Barbeau and his team. After having analysed the data they collected, Barbeau et al. got to the conclusion that “IPL appears to play a special role in language learning” (Barbeau et al. 2017: abstract). As phrenology did in the past, researches like this one presuppose that some specific mental processes (in this case, second language learning) are linked to some neural changes, but this link is controversial (Uttal 2001; Van Orden and Paap 1997). We are not denying the existence of neural changes linked to mental processes; we are positing that we cannot clearly define the concept of mental process, even if we can detect with great precision a spatial localization in the brain. Perhaps in the future problems linked to spatial resolution of brain imaging techniques will be solved; in that case, we will be able to spot with great precision the spatial localization of IPL. However, what does it mean to be precise when we talk about the concept of “language learning” (cfr. on the topic Uttal 2001)?

Barbeau et al. tried to answer this question: in their study, IPL showed to be activated in L2 learners more after their linguistic training than before; the level of activity in IPL was successfully correlated to L2 behavioural tests; the level of activity in IPL before the training was correlated to an improvement in reading speed of L2 after the linguistic training (Barbeau et al. 2017).

In order to assume that IPL plays a special role in language learning, researchers had to embrace some hypothesis that were neither implausible nor sure: the idea that a higher physiological activity in the observed areas implies a determinant functional role of them; the idea that the traces the researchers perceived within the 10 seconds of activity were relevant from a functional point of view; the supposition that there is a causal relation between the increasing found in the activity of the
brain and the improvement in the function, etc.

Even if they have a lot of limits, the fMRI studies could be helpful for cognitive sciences, provided that researchers use techniques like this (and the other brain imaging tools) aware of their unsuitability to explain certain functions. Figuratively speaking, we could say that the increase in the metabolic activity of IPL following L2 learning could be compared to the increasing in legs’ muscle mass following an intense gym training.

What does neuroscience miss about the concept of mind?

4. Embodied, embedded, enacted, extended cognition and second language acquisition

In 1991, Francisco J. Varela, Evan Thompson and Eleanor Roch published *The Embodied Mind: Cognitive Science and Human Experience*. This book triggered a new conception of mind based on two main theoretical principles:

We cannot represent mind through algorithms.

We cannot study mind without considering the role of the wholebody in cognitive processes.

This theoretical operation takes the name of *embodiment*. A mind (or a cognition) that is *embodied* is also “situated”. The philosophical precursor of this point of view is probably James Gibson who, with his concept of *affordance*, integrated the environment and other social entities as active agents in cognitive processes. According to Gibson “the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill […]. It implies the complementarity of the animal and the environment” (Gibson 2015:119). I. e., the voice of someone that is talking to us is a social affordance because is what environment offers us in order to interact with it and to get integrated in it.

Mark Rowlands (2010)—in referring to a previous categorization orally elaborated by Shaun Gallagher—well-synthesized the characteristics of the notion of cognition that emerges from this new point of view, using the expression *4E of cognition*. In this perspective, mind is *embodied; embedded; enacted and ex-
When we talk about the embodied mind we mainly focus on the importance of bodily structures for cognition. The embedded aspects of cognition are the ones related to the environmental context. The enacted perspective highlights the importance of sensory-motor activities and lastly, when we talk about extended mind we refer to all the elements of the environment (technological tools, social agents, environmental affordances, etc.) and the body that interact one with each other.

This approach is giving a new impetus to the question of the ontogenetic development of language. We are learning to consider some social affordances as fundamental elements for the triggering of linguistic development (Pennisi 2016); some exempla could be the eyes of others; natural bodily messages such as the communication of emotions through biological motion and universal facial expressions; or the spontaneous and universal baby talk (Falk 2011).

Unfortunately, this approach has rarely been applied to the study of SLA. The linguist Dwight Atkinson in recent years tried to develop a theoretical construction of SLA based on the embodiment of cognition. I.e. in 2010 he tried to show, through the analysis of a case study, what is the role of the context in the acquisition of a second language. What we want to do here is to integrate the data collected by Atkinson with other data that were not produced within the context of embodied cognition (EC) theories, in a way coherent with our idea.

I.e. let’s consider the role of eye movements in SLA. Out of EC approaches, some studies on this phenomenon have been carried out in the last years through the use of eye-trackers. This methodology was mainly used in two ways. The first is the analysis of eyemovements during a sentence reading task (see i.e. Frencck-Mestre 2005; Godfroid et al. 2013); this is the most used strategy based oneye-tracking (Roberts and Siyanova-Chanturia 2013). However, other experimental settings, based on listening input, showed a good ecological validity. A successful method is studying cognitive interference between the two languages: in some setups, while hearing a word the participants had to match it with one option out of the four
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that were displayed on a monitor in front of them. While they were doing this, experimenters pronounced some words that could create phonetic interference of various kind. Thanks to this method, different studies showed that first and second language interact in listening recognition tasks (Blumenfeld and Marian 2011; Culter et al. 2006; Weber and Culter 2003). Thus, even if we cannot analyse these studies, the point is that we can study cognitive phenomena, such as SLA, through bodily processes like eyemovements.

Other important sources of information are general bodily attitudes. I. e. let’s consider mimicry. Mimicry is the unaware synchronization with others’ body postures, facial expressions, prosody, gestures, etc. that usually occurs during social interactions. Someone hypothesized that mimicry is linked with the desire to establish a relation with other speakers (Lankin and Chartrand 2003). In general, mimicry is considered a personal skill: some individual are more able than other to mimicry. Martin Hinton, in 2013, showed that mimicry ability seems to be a strong predictor of pronunciation learning, because it is strictly linked to the acquisition of the foreign accent. More recently, Ying Li (2016) showed that mimicry ability in L1 Mandarin speakers have a correlation with their ability to pronounce French sentences. Moreover lip-reading is determinant in order to get an early oral comprehension of a foreign language (Li and Somlak 2017).

Through an overview of current studies, Marianne Gullberg (2008) showed that the study of communicative gestures during 2L perception or production let us know what aspects of a communicative events are more salient for L2 learners and what kinds of information are usually packaged together in a same concept and how.

5. Conclusions: proposal for the future

In this paper we reconstructed the consequences that the changes that occurred in the theoretical background of cognitive sciences had on the studies on SLA. Although computationalism and disincarnated paradigms are slowly weak-
ening, they should not be erased from the historical memory, because traces of them can still be useful in order to provide active contributions to modern theories.

EC approaches are a new historical attempt to overcome cartesian dualism. In embracing the EC perspective, we proposed an integrated view of the concept of mind. In doing so, we proposed to consider classical linguistic approaches, neuroscientific studies and more general considerations about the body’s interaction with the environment as a part of SLA studies. When we talk about body, we mean the integrated body-brain complex; when we talk about the environment, we mean social interactions, physical characteristics of the environment and the use of technological tools. The examples we took from the literature on the importance of eye-motion analysis, mimicry and gestures are all related to the study of the body as a whole. Studies focused on body are a small percentage, that at least is in development. Unfortunately, we do not have enough space to detail on the integration among the technological, social and physical components, but we will develop the topic in a near future.

The ultimate aim of this work was to propose the launch of a new methodology for the study of SLA, based on the most advanced cognition theories. Therefore, we hope we have provided some practical exempla and theoretical explanations of how and why we think it would be appropriate for research to move in this direction.

Technical note of authors

This work is the result of a common reflection followed by long theoretical debates between the two authors, but in particular the §1 and §5 are attributed to Patrizia Torricelli; on the contrary, §2; §3 and §4 are attributable to Paola Pennisi.

Bibliography

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